DISCUSSION
7.0

Office of the Superintendent of Schools
MONTGOMERY COUNTY PUBLIC SCHOOLS
Rockville, Maryland

August 24, 2006

MEMORANDUM

To: Members of the Board of Education

From: Jerry D. Weast, Superintendent of Schools

Subject: Girls in Information Technology Task Force Report

Executive Summary

The purpose of this discussion item is to present the report and recommendations of the Montgomery County Girls in Information Technology (IT) Task Force (Attachments A and B). The recommendations focus on ways in which to improve the participation of female students in IT fields through marketing and recruiting, retention and culture building, and curriculum and professional development involving the Montgomery County Public Schools (MCPS) and other partners in K–16 education in Maryland and the greater Washington area.

Background

In March 2005, the Montgomery County Commission for Women requested that MCPS convene a Girls in IT Task Force to address the crisis involving the national, state, and regional shortage of women entering IT-related career fields and the lack of female enrollment in MCPS technology programs. The Girls in IT Task Force was charged with the following responsibilities:

- Recommend strategies for increasing the participation of girls in IT-related programs.

- Communicate task force recommendations in the form of a report to be presented to the Montgomery County Board of Education in summer 2006.

The Girls in IT Task Force is a multi-stakeholder group chaired by Ms. Nancy Floreen, member, Montgomery County Council, and vice-chaired by Ms. Carroll McGillin, National Initiatives Manager, Cisco Networking Academy Program, Cisco Systems, Inc. The Girls in IT Task Force met regularly to review and discuss research, explore model programs and best practices, and develop a technology agenda for K–12. A steering committee, representative of the make-up of the Girls in IT Task Force, guided the direction and monitored the progress of the group.

The Girls in IT Task Force identified the following three major issues and developed corresponding project teams to conduct research and develop recommendations:

- Marketing and Recruiting
- Retention and Culture Building
- Curriculum and Professional Development

Recommendations

The Girls in IT Task Force developed the following set of recommendations to ensure that girls and underrepresented populations within MCPS are prepared to enter the workforce with critical IT skills:

Marketing and Recruiting

- Create a comprehensive marketing plan to raise the awareness of parents/guardians and educators that the skills and talents of girls are vital to technology-related professions.

Retention and Culture Building

- Create and expand articulated and integrated IT programs over stand-alone courses.
- Develop options to provide culture-building and supportive experiences.

Curriculum and Professional Development

- Partner with business and higher education to create a seamless K–16 educational system that aligns curriculum and requires technology-related units or course work by all K–12 students by 2010.

Next Steps Suggested by the Girls in IT Task Force

To ensure success for the issues related to the three project teams, the task force suggests the following next steps:

- Involve additional stakeholders to further develop and implement the recommendations.
- Develop a plan during the 2006–2007 school year to address the task force recommendations that includes a timeline, budget, and implementation activities, maintaining focus on scalability and sustainability.

- Conduct an audit of MCPS curriculum to determine where technology instruction already exists, and complete a gap analysis plan for addressing areas of deficit.

- Collect baseline data for current IT-related program and course enrollment. Institute an accountability and review system to identify "what success looks like" and measure progress.

- Plan and launch "rapid prototypes" (pilots) of several research-based IT-focused initiatives, leveraging existing programs and resources as well as monitoring success.

I have asked staff to review the task force findings and recommendations and provide me with a response and corresponding plan. During the year, I will keep you apprised of the progress on this issue. I would like to commend all task force members and recognize them for their extensive commitment to these efforts. In particular, I want to recognize our business partners from the private sector who contributed greatly to this project. Finally, I also would like to thank Ms. Nancy Floreen, member of the Montgomery County Council, for chairing this task force.

At the table today to present the Girls in IT Task Force report are Ms. Anne Albright, business unit executive, IBM; Ms. Shan Carr Cooper, vice president, Diversity and Equal Opportunity Program, Lockheed Martin; Ms. Nancy Floreen, Montgomery County Council Member and IT Task Force Chair; Ms. Shelley A. Johnson, director, Division of Career and Technology Education; and Ms. Diane Murray, principal, Booz Allen Hamilton, Inc.

Providing testimonials today are Ms. Amy Bielski, president and CEO, Ripple Effect Communications, Inc.; and Ms. Tena Hunter, Academy of Information Technology student, Gaithersburg High School.

JDW:JAL:lsj

Attachments

Montgomery County
Technology Action Agenda for K-12

Preparing Our Children for the Future

Developed by the Girls in Information Technology (IT) Task Force

Rockville, MD
August 24, 2006

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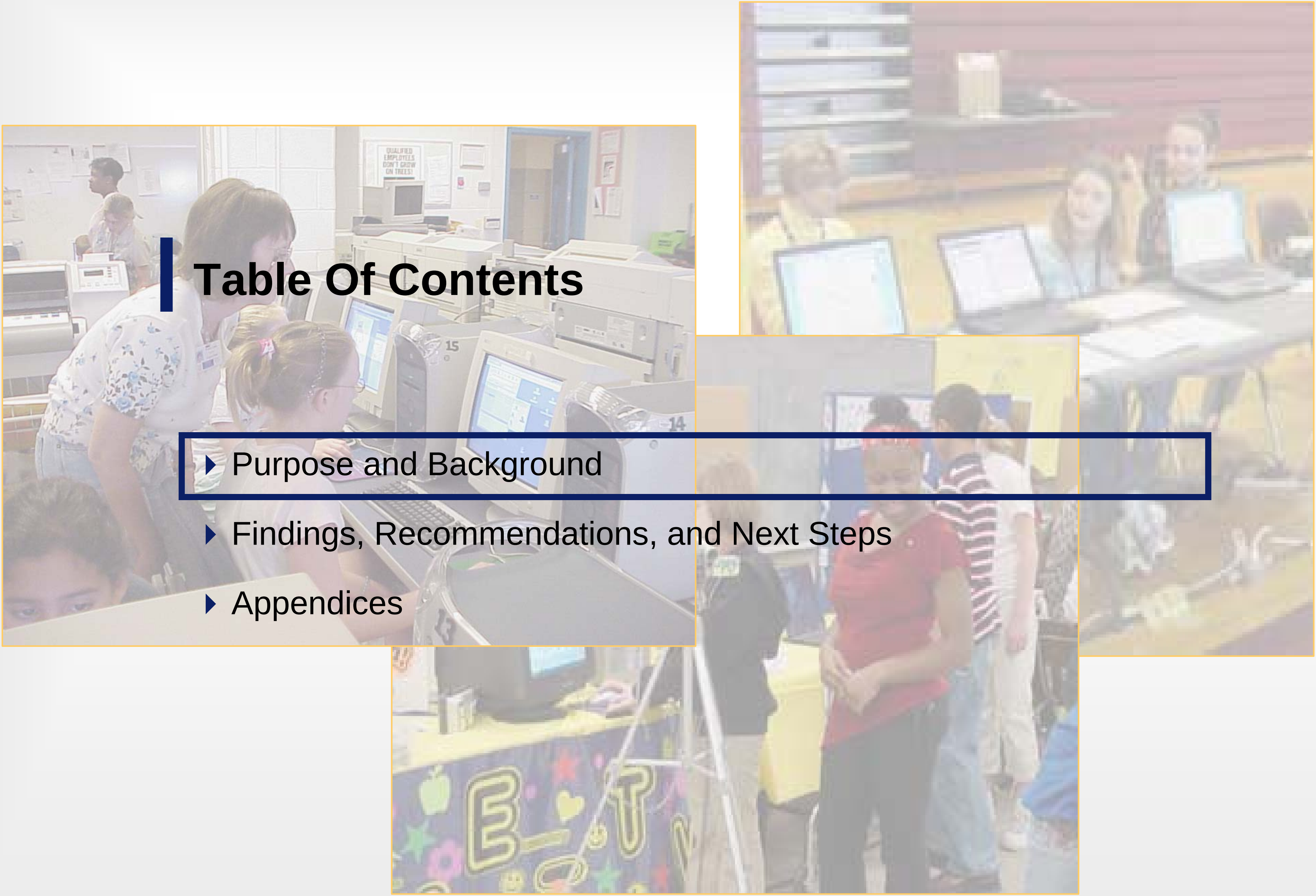


Purpose and Background

The Girls in Information Technology (IT) Task Force was formed to address the significant underrepresentation of females in existing MCPS technology programs and courses…

Task Force	
Government and Non-Profit Organizations	
Montgomery County Council	Nancy Floreen – Task Force Chair
Maryland House of Delegates	Anne Kaiser
Montgomery County Business Roundtable for Education	Jane Kubasik
Montgomery County Commission for Women	Judith Vaughan-Prather
Montgomery County Government Department of Technology	Alisoun Moore – Project Team Chair
Washington Area Women's Foundation	Marion Ballard
Education	
Montgomery College	Katherine Michaelian
Montgomery County Public Schools	Casey Crouse, Anne Contney, Laura Grace, Shelley Johnson, Sandra Navidi
University of Maryland, Baltimore County, Center for Women and Information Technology	Claudia Morrell

…and was comprised of members from a variety of regional community organizations and businesses.

Task Force	
Business	
Cisco Systems, Inc.	Carroll McGillin – Task Force Vice-Chair and Project Team Chair
Booz Allen Hamilton, Inc.	Diane Murray
Freddie Mac	Marla Ozarowski
IBM	Anne Albright – Project Team Chair
Lockheed Martin Corporation	Shan Carr Cooper and Meredith Rouse Davis
T-Alpha Networks	Walter Lee, Jr
Verizon	Briana Gowing

The Task Force identified three key issues and created project teams for each to conduct research and make recommendations.

Task Force Project Teams

Key Issues and Questions

- *How do we change the stereotype that technology is only interesting to boys?*
- *How do we effectively deliver the message to students, parents, and educators that girls pursuing technology careers are vital to America staying competitive?*

- *How do we retain girls in IT programs and encourage them to enroll in a sequence of rigorous IT courses?*
- *How can we design IT pathway programs to create a culture that supports success and provides rigor, relevance, and relationships?*

- *What are the characteristics of the current IT curriculum, and how does it align with the interests and learning styles of girls?*
- *How do we ensure that the technology courses offered align with the needs of the business community?*
- *How do we ensure that our teachers and other educators are equipped to teach an expanded IT curriculum?*

Data indicate that MCPS elementary school girls and boys have similar interests in IT topics, but female interest begins to decline during middle school and drops off dramatically in high school.

Girls and boys share enthusiasm for IT in elementary school.

Elementary School

By Grade 8, half as many girls as boys show interest in IT careers.

Middle School

In high school, boys outnumber girls by 4:1 in most IT-related courses.

High School

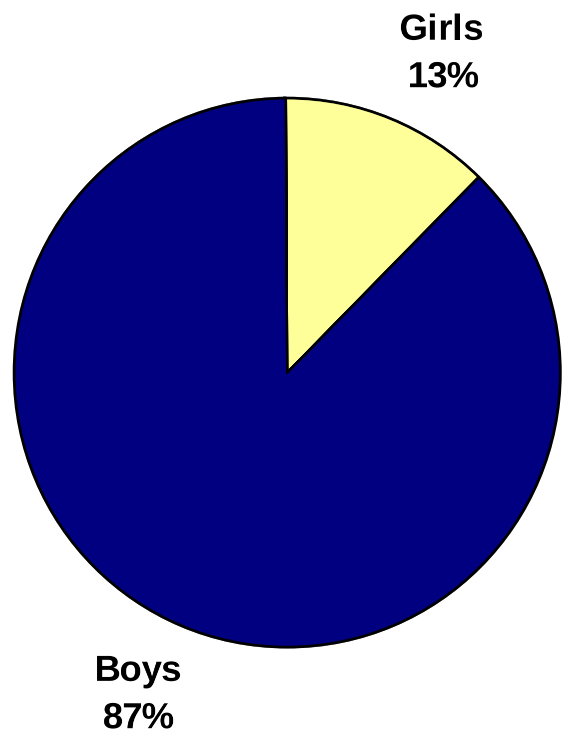
"…by Grade 8, half as many girls as boys show interest in careers that require math, science, and technology knowledge and skills. As a result, far fewer girls are positioned for technology professions."

Jo Sanders, Director
Center for Gender Equity - 2006

Purpose and Background

MCPS Advanced Placement Computer Science course data clearly indicate that girls are not represented in proportion to the population of all girls in high school…

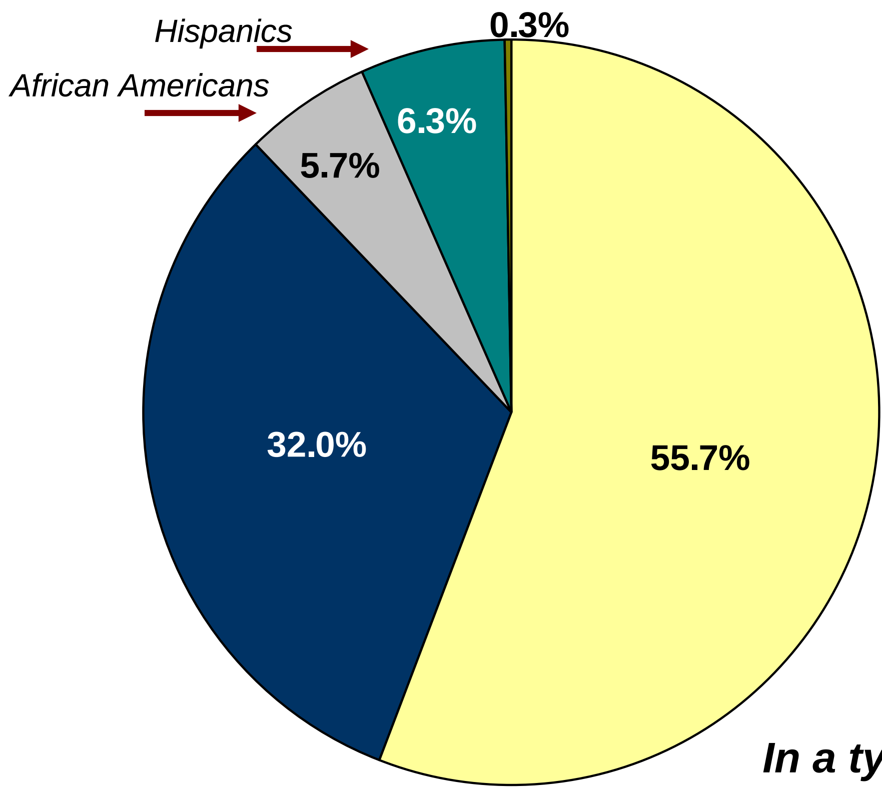
2005 MCPS Advanced Placement Computer Science



In a typical MCPS Advanced Placement Computer Science class of 30 students, only 4 are girls.

… and that other underrepresented groups exist and would benefit from interventions as well.

2005 MCPS Advanced Placement Computer Science



MCPS Demographics
June 2006

- White - 42.0%
- Asian - 14.7%
- African American - 22.9%
- Hispanic - 20.1%
- Native American - .3%

In a typical MCPS Advanced Placement Computer Science class of 30 students, only 2 are African American and 2 are Hispanic.

Purpose and Background

MCPS data mirror an existing shortage of women and other underrepresented populations in science, engineering, and technology fields.

"Today's U.S. economy depends more than ever on the talents of skilled, high-tech workers. To sustain America's preeminence we must take drastic steps to change the way we develop our workforce. An increasingly large proportion of the workforce consists of ***women****, underrepresented minorities, and persons with disabilities—groups not well-represented in science, engineering, and technology (SET) fields. Unless the SET labor market becomes more representative of the general U.S. workforce, the nation may likely face* ***severe shortages*** *in SET workers, such as* ***those already seen in many computer-related occupations."***

- Source: "*Land of Plenty Diversity as America's Competitive Edge in Science, Engineering and Technology"* – September 2000
- *Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development; National Science Foundation*

National projections indicate that 5 of the 10 fastest-growing occupations will be IT-related in 2014.

Occupation - 2004 National Employment Matrix code and title	Number of Jobs Created (2004-2014)	Percent Growth (2004-2014)	Earnings Category
15-1081 Network systems and data communications analysts	126,000	54.6%	Very High
29-1071 Physician assistants	31,000	49.6%	Very High
15-1031 Computer software engineers, applications	222,000	48.4%	Very High
31-2021 Physical therapist assistants	26,000	44.2%	High
29-2021 Dental hygienists	68,000	43.3%	Very High
15-1032 Computer software engineers, systems software	146,000	43.0%	Very High
15-1071 Network and computer systems administrators	107,000	38.4%	Very High
15-1061 Database administrators	40,000	38.2%	Very High
29-1123 Physical therapists	57,000	36.4%	Very High
19-4092 Forensic science technicians	4,000	36.7%	Very High

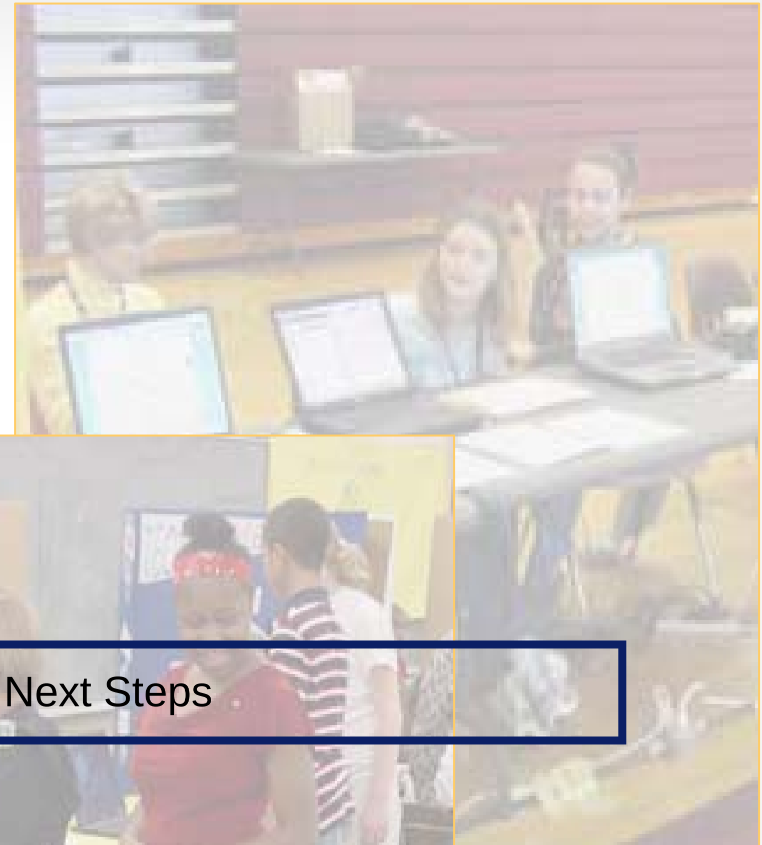
- *Source: Bureau of Labor Statistics, http://www.bls.gov/emp/emptab21.htm*

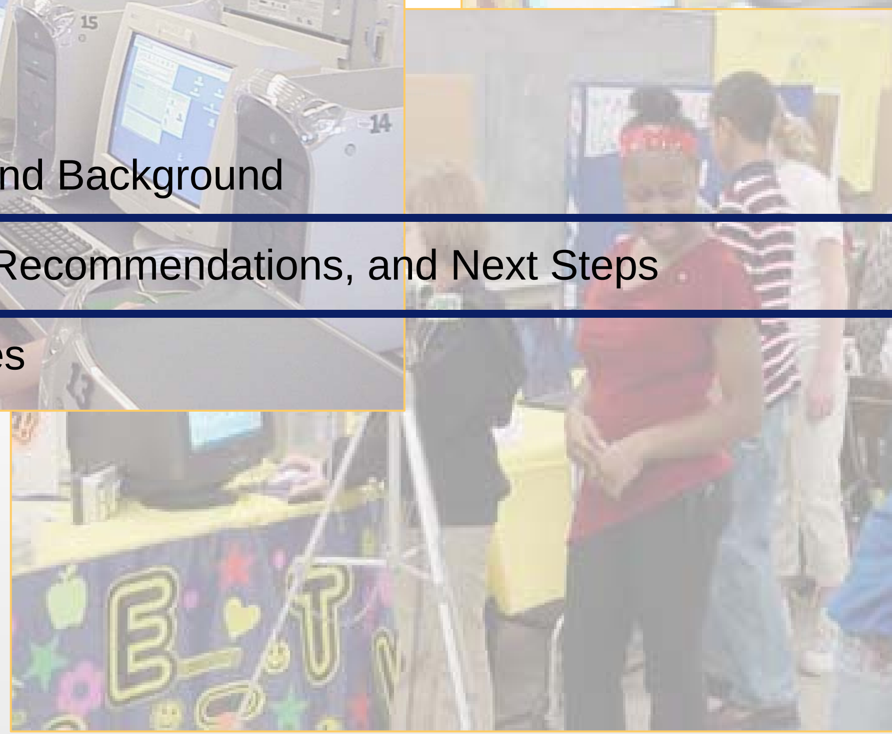
Current ninth graders will be entering the workforce as college graduates in 2014. If action is not taken now, girls and other underrepresented groups will not be positioned for successful future careers in IT.

President Bush promotes the *Keeping America Competitive* initiative at MCPS middle school, Parkland Magnet School for Aerospace Technology, on April 18, 2006.

- ***Diversity of ideas and approaches*** *are important to ensure innovation and creation of new products and services.*
- *Employers have recognized a* ***lack of females*** *and other underrepresented groups within the technology industry.*
- *Employers are working to provide resources that will enable regional educational programs to be delivered.*

Leaders and technical experts across all segments of our population must be developed to meet demand.





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Near-term action is necessary to increase interest and involvement of girls and underrepresented populations in IT.

Summary Findings

Marketing and Recruiting

- Perception among girls is that IT courses are not relevant to their lives and the course work is only interesting or relevant to boys.
- Parents/guardians and educators are less likely to encourage girls to enter the IT field.
- Parents/guardian and educators are unaware of the demand for talent or the type of opportunities available in the IT field.

Retention and Culture Building

- When a systemic approach is employed to create pathway programs vs. stand-alone courses, a culture is established which promotes rigor, relevance, and relationships – encouraging retention and success.
- In 2005-06, MCPS piloted promising middle and high school IT program models, but the capacity to expand these programs is currently limited.
- MCPS has a limited accountability and review system to measure progress and ensure student retention and success in IT programs.

Curriculum and Professional Development

- The delivery of the technology courses offered in high school seems out of alignment with the IT industry.
- IT courses are not part of the core academic curriculum, and the learning context in which they are presented (traditional content approach) is not designed to appeal to the interests and learning styles of girls.

MCPS Challenges

Recruit more girls into IT programs and raise awareness for the need of their talents in related professions.

Create IT pathway programs that provide a culture and support system to ensure girls successfully complete rigorous IT course sequences.

Ensure course work has continued relevancy in a rapidly-changing technical environment and that end-of-course or program goals are in alignment with industry needs.

Marketing and Recruiting Team findings indicate that many girls and underrepresented groups don't find IT courses relevant to their lives and are not encouraged to pursue IT course work…

What Should We Do?

- ✓Deliver targeted messages that "get the word out" to girls and underrepresented populations that IT is **fun, exciting** and can **make a difference** in their lives
- ✓Encourage "technology equity" early by developing a systematic approach to math and science as foundational course work

- ➔Start recruiting activities early – before Grade 6
- ➔Conduct more inclusive, targeted marketing of IT course work
- ➔Technology fairs, competitions and other events that involve the local business community – especially women in IT careers
- ➔Enlist local women's groups
- ➔Public Service Announcements, point of service advertising

How Should We Do It?

… and media and advertising tend to portray men in technical roles more often than women

Retention and Culture Building Team findings indicate that successful technology outreach programs provide an integrated pathway that gives students varied experiences and interactions.

What Should We Do?

- ✓ Create comprehensive technology pathway programs
- ✓ Expand successful MCPS IT pilot programs and leverage successful national models and best practices
- ✓ Partner with business, postsecondary education, and non-profit organizations to provide culture-building and support experiences

- ➔ Integrate core academic courses with technology courses in a multi-year program
- ➔ Include opportunities for student internships and capstone projects
- ➔ Establish educational partnerships and an advisory board system
- ➔ Multi-year counseling and parent seminars
- ➔ Orientation programs and summer camps
- ➔ Mentoring and tutoring

How Should We Do It?

Role models, teacher enlightenment, and hands-on-experience are key components.

Curriculum and Professional Development Team findings indicate that IT courses are not part of the core curriculum, and the current learning context is not engaging all students.

What Should We Do?

- ✓Require an IT unit/module or course at each grade level, K-12 by 2010
- ✓Structure the technology program (K-12) to create a learning environment that is engaging to females and other underrepresented groups
- ✓ Engage business and higher education partners in the ongoing review of IT course content
- ✓Ensure IT teachers have appropriate industry training and certification

- ➔Conduct a curriculum audit to assess content and completeness, and identify potential sources of bias
- ➔ Develop interdisciplinary courses for high school that are centered on solving real-world problems
- ➔Provide Honors designation for IT course work
- ➔Establish MCPS competencies for teacher IT skills
- ➔Work with business to implement incentive and recognition programs for exemplary IT teachers

How Should We Do It?

Lack of funding for both professional development and expanding/revising the current curriculum also are concerns.

Key recommendations were developed to ensure that the design of MCPS IT instruction addresses equity for gender and ethnicity.

Marketing and Recruiting

- Create a comprehensive marketing plan to raise the awareness of parents/guardians and educators that the skills and talents of girls are vital to technology-related professions.

Retention and Culture Building

- Create and expand articulated and integrated IT programs over stand-alone courses.
- Develop options to provide culture-building and support experiences.

Curriculum and Professional Development

- Partner with business and higher education to create a seamless K-16 educational system that aligns curriculum and requires technology-related units or course work for all K-12 students by 2010.

The four Task Force recommendations were aligned with MCPS Strategic Plan goals.

❶ *MCPS Goal 1: Ensure Success for Every Student*

- The Task Force recommendations are targeted at student populations that are traditionally underrepresented in IT courses, activities, and careers.

❷ *MCPS Goal 2: Provide an Effective Instructional Program*

- It is recommended that a more rigorous and relevant IT instructional program is developed and implemented that appeals to all segments of the student population and that IT-related units or course work are required at each grade level to ensure equity.

❸ *MCPS Goal 3: Strengthen Productive Partnerships for Education*

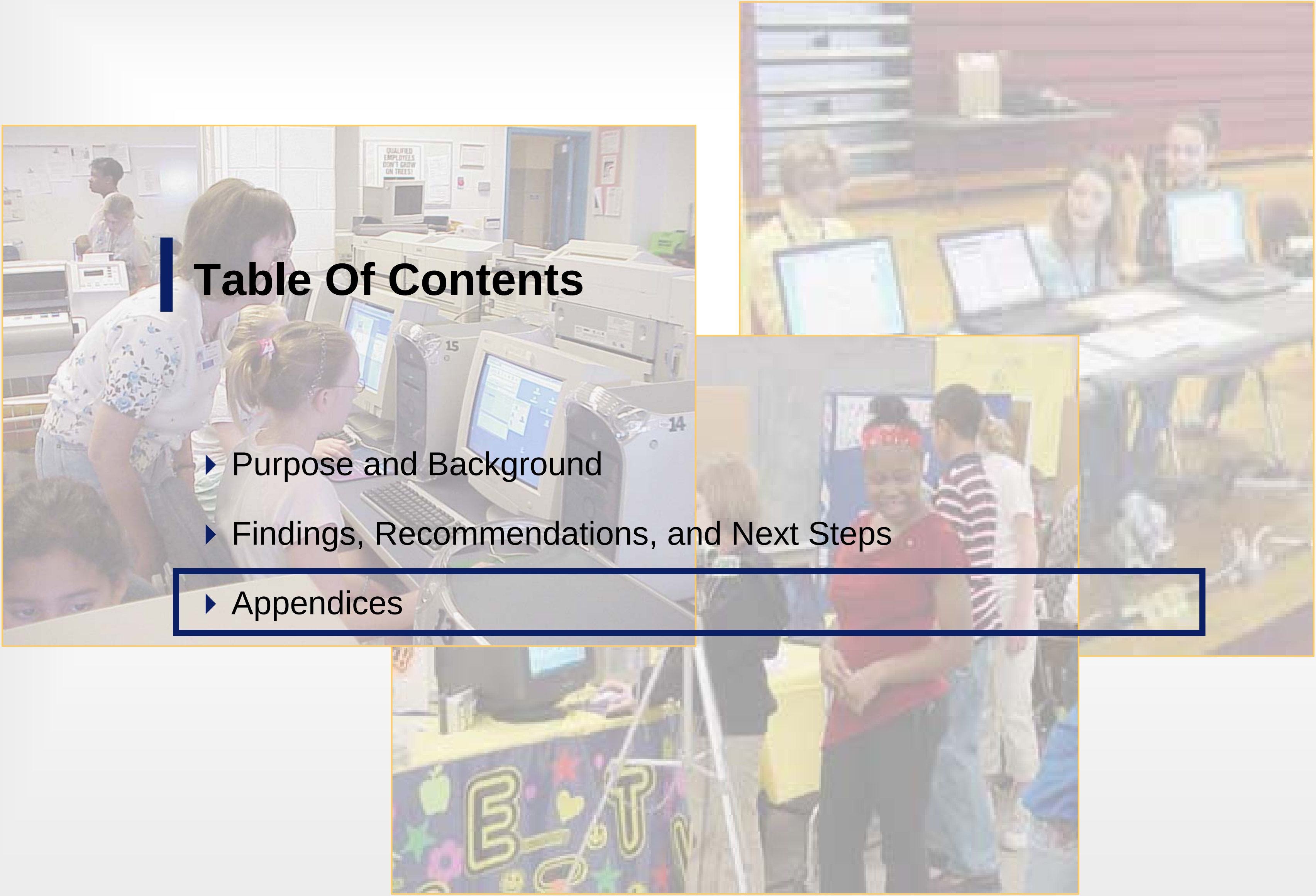
- The Task Force is actively engaged with the business community and other educational and government organizations to ensure that best practices are leveraged, taking advantage of existing programs and resources, and that support is garnered from stakeholders who have a vested interest in the success of the recommendations.

❹ *MCPS Goal 4: Create a Positive Work Environment in a Self-renewing Organization*

- The Task Force recommendations include training and support for MCPS educators and include performance measures to ensure that the school system can evaluate progress.

Next steps must address all three issues identified by the Task Force.

- Involve additional stakeholders to further develop and implement the recommendations.
- Develop a plan during the 2006 – 2007 school year to address recommendations that includes a timeline, budget, and implementation activities, maintaining focus on scalability and sustainability.
- Conduct an audit of MCPS curriculum to determine where technology instruction already exists, and complete a gap analysis to plan for addressing areas of deficit.
- Collect baseline data for current IT-related program and course enrollment. Institute an accountability and review system to identify “what success looks like” and measure progress.
- Plan and launch “rapid prototypes” (pilots) of several research-based IT-focused initiatives, leveraging existing programs and resources as well as monitoring success.



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Montgomery County
Technology Action Agenda for K-12

Developed by the Girls in Information Technology (IT) Task Force

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Appendices

- **Appendix A**

  Project Team Detailed Findings,
  Recommendations, and Implementation Strategies

Girls in IT Task Force Definition of
"Information Technology"

Information technology represents the core skill set that serves as a* foundation *for all technology-related careers including
information sciences, computer science, biotechnology, manufacturing, and engineering.

Marketing and Recruiting Team

Detailed Findings, Recommendations, and Implementation Strategies

Key Findings	Recommendations	Implementation Strategies
• Many girls and other underrepresented groups feel that technology-related courses are not relevant to their lives and see no need to take them. • There is still a perception by secondary female students that information and communication technology programs are only relevant or interesting to the male culture; therefore, they would neither be capable of completing the course work nor interested in participating. • Participation in MCPS technology-related elective courses does not mirror the systemwide student enrollment data. Girls and underrepresented populations are enrolled at lower rates with the discrepancy increasing as courses become more advanced. (See Appendix B.) • Generally, parents/guardians and educators are less likely to encourage girls and other underrepresented groups to enter technology fields. • Students, parents/guardians, educators, administrators, and the public-at-large are unaware of the future demand for technology-related careers. • Advertisements in technology magazines tend to portray men in more technical roles than women.	• Encourage equitable participation in professional technology experiences for girls and other underrepresented groups by providing a systemic approach to math and science skill sets as foundational elements for all coursework. • Deliver messages and communications in various forms to correct the perception that girls and other underrepresented groups are not capable of or interested in technology-related programs.	**School based supports:** • Use data to target girls and other underrepresented groups for technology coursework. • Reach out to the feeder schools to begin recruitment earlier than Grade 6. • Increase teacher and school counselor awareness of the technology opportunities available for girls and other underrepresented groups. • Market technology coursework in a way that is inclusive of girls and other underrepresented groups. **Community based supports:** • Create and air public service announcements. • Develop and distribute point-of-service advertising (mailings, online advertising, etc.). • Sponsor outreach and academic events, such as competitions and fairs, that directly involve employees on their jobsites. • Use existing local women's groups and other organizations and individuals who will "get the word out."

Retention and Culture Building Team

Detailed Findings, Recommendations, and Implementation Strategies

Key Findings	Recommendations	Implementation Strategies
‣ When a systemic approach is employed to create pathway programs vs. stand-alone courses, a culture is established which promotes rigor, relevance, and relationships. The culture helps to retain and support students. MCPS is implementing promising IT program models, but the capacity to expand these programs is currently limited. ‣ During the 2005–06 school year, the vast majority of high school students were enrolled in IT courses versus IT pathway programs that support student success. MCPS offers IT focused magnet programs at three middle schools and is piloting a national IT model program at six high schools. ‣ A survey of national non-profit organizations with youth outreach programs in technology provided the following common factors: hands-on experiences, use of role models, co-curricular activities, and teacher enlightenment programs. ‣ Programs that have a data-collection system for measuring retention and achievement have demonstrated a positive impact for students in all populations. Currently, MCPS has a limited accountability and review system to measure progress and ensure student success in IT programs.	‣ Create state-of-the art technology pathway programs versus stand-alone courses. ‣ Expand successful MCPS IT pilot programs and leverage national models and best practices. ‣ Partner with business, postsecondary education, and non-profit organizations to provide culture-building and support experiences. ‣ Develop a system of data-collection that allows for measurement and monitoring of students over time to ensure that capable students are encouraged to remain in advanced pathway programs.	‣ Create articulated and integrated IT programs that: – Integrate core academic courses with technology courses in a multi-year program, – Schedule students in a cohort for program courses, – Employ a team approach for instruction, – Include opportunities for student internships and capstone projects, and – Establish educational partnerships and an advisory board system. ‣ Develop options to provide culture-building and support experiences from which schools may select: – Orientation programs and summer camps, – Student professional conferences, seminar series, field trips, job shadow experiences, – Events to showcase capstone projects, – Special events: induction, pinning, graduation, senior banquet, awards, – Mentoring and tutoring programs, – Multi-year counseling system, and – Parent Seminars.

Curriculum and Professional Development Team

Detailed Findings, Recommendations, and Implementation Strategies

Key Findings	Recommendations	Implementation Strategies
• No Child Left Behind requires technology literacy for all students by Grade 8. While Montgomery County Public Schools (MCPS) is preparing to adopt tech literacy standards (TL8), there is no district-wide implementation plan or accountability process for measuring attainment, (i.e. end-of-course or unit assessment). • Some of the information technology (IT) course content and design seem out of alignment with those required in the job market. The IT industry sees the need for a diverse workforce as an issue of economic competitiveness and requires a K–12 technology curriculum that attracts and retains females and other underrepresented groups, particularly in the high school level technology courses. • Current MCPS IT courses are programming, networking, hardware maintenance, database, and Web site development. While the content is valuable, the context of learning is critical to attracting and retaining females into IT courses. Research shows successful technology programs utilize project- and problem-based learning that teaches students how to apply what they learn to real-life situations (design-based learning). • MCPS IT courses are considered electives, not part of the core academic curriculum; only programming courses currently have honors designation. Students have little incentive to explore a challenging IT course without an honors designation. • Traditional curriculum design and in-service models do not accommodate the rapid technology advances (e.g. bio-tech, nano-tech) that impact both technology course development and the need for teacher professional development.	• Engage business and higher education partners in the ongoing review of IT course content, professional development, and real-world applications that connect classroom learning to the workplace. • Ensure that the K–12 technology program is structured to create a learning environment that engages females and other underrepresented groups, and that educators receive the appropriate professional development to reach that goal. • Require an IT unit/module or course at each grade level, K–12, by 2010.	• Conduct a curriculum audit to determine what technology units and courses currently exist and what is missing. • Review the current MCPS curriculum to identify what biases may exist in framework goals or materials. In particular, identify factors in the IT courses that impact recruitment and retention of females and other underrepresented groups into IT programs. • Develop IT courses at the middle school and high school levels that are more broad-based and interdisciplinary with a focus on learning that is built around using technology to solve real-world problems. • Provide honors designation for middle school and high school technology coursework to entice students to participate. • Offer IT courses, such as *Software Applications by Design*, at the middle school level so that students may receive high school credit. • Expand the opportunities for dual-enrollment coursework as part of IT pathway programs. • Investigate current national models for developing a self-appraisal system for professional development. • Establish MCPS competencies for teacher IT skills based on state/national best practices. • Dedicate teacher in-service days to IT enrichment and best

- IT teachers coming from industry often lack the pedagogy background for successful instructional engagement.		practices in gender and cultural diversity.

Curriculum and Professional Development Team

Detailed Findings, Recommendations, and Implementation Strategies

Key Findings	Recommendations	Implementation Strategies
• As K–12 technology standards are implemented, there is no appraisal system for teachers to assess their current technology skills and determine their professional development needs related to technology. • Currently within MCPS, there is little to no funding at the elementary and middle school level that is specifically designated for IT-related professional development. • High school funding for IT pathway programs is dependent upon Perkins grants obtained through the Maryland State Department of Education. This funding is contingent upon annual legislation.	• Provide adequate funding to enable a meaningful and on-going teacher professional development program.	• Incorporate research-based best practices in gender and cultural diversity into the professional development model for IT teachers. • Work with the business community to implement incentive and recognition programs for exemplary IT teachers. • Work with the business community to identify IT mentors for female teachers in IT, especially for teachers with no IT industry background. • Pursue grants that support innovative ways to recruit and train IT instructors.

Appendices

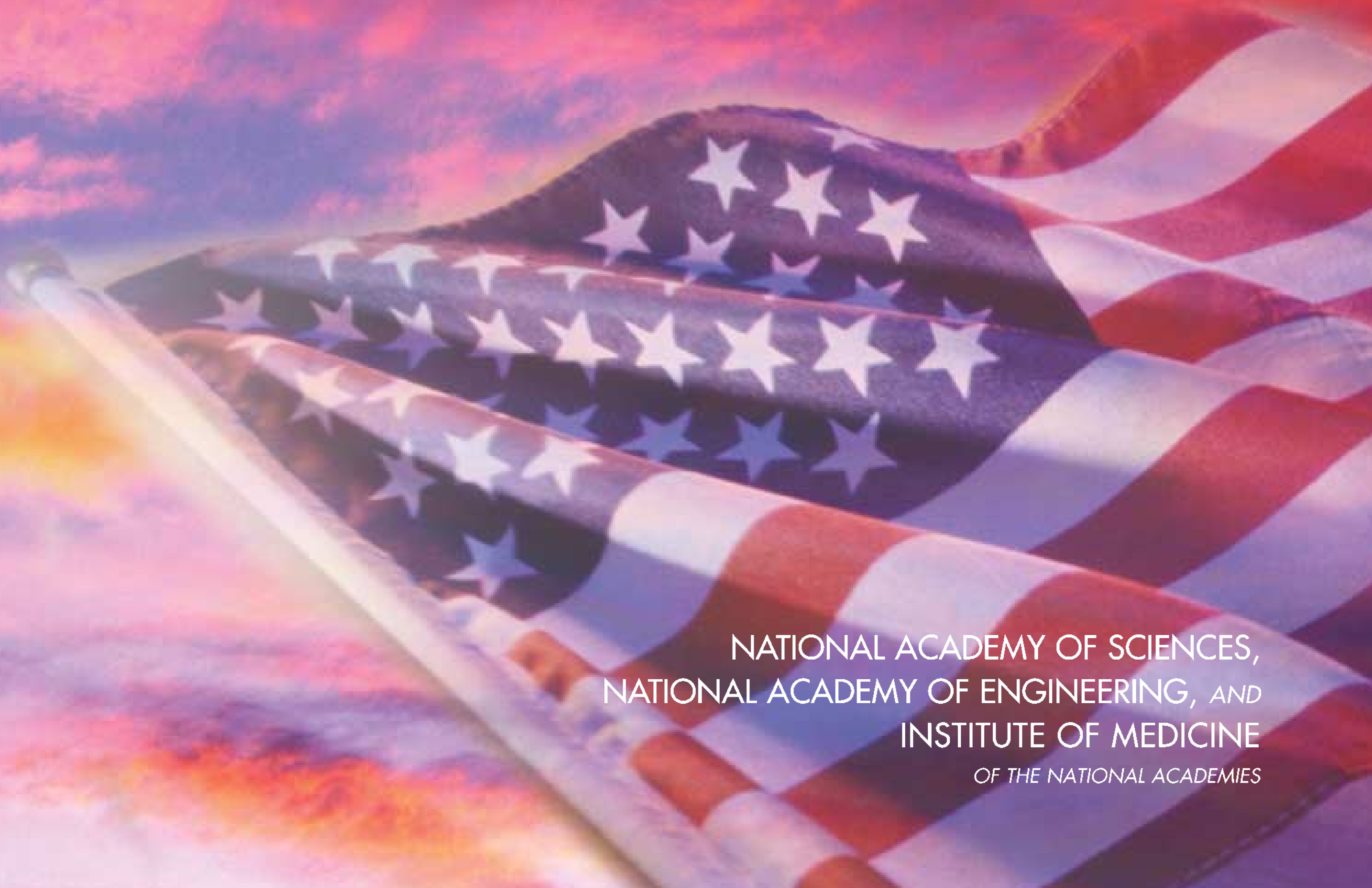
- **Appendix B**

  Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future

EXECUTIVE SUMMARY

RISING ABOVE THE GATHERING STORM

Energizing and Employing America for a Brighter Economic Future



NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, *AND*
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

COMMITTEE BIOGRAPHIC INFORMATION

NORMAN R. AUGUSTINE [NAE*] (Chair) is the retired chairman and CEO of the Lockheed Martin Corporation. He serves on the President's Council of Advisors on Science and Technology and has served as undersecretary of the Army. He is a recipient of the National Medal of Technology.

CRAIG BARRETT [NAE] is chairman of the Board of the Intel Corporation.

GAIL CASSELL [IOM*] is vice president for scientific affairs and a Distinguished Lilly Research Scholar for Infectious Diseases at Eli Lilly and Company.

STEVEN CHU [NAS*] is the director of the E.O. Lawrence Berkeley National Laboratory. He was a cowinner of the Nobel prize in physics in 1997.

ROBERT GATES is the president of Texas A&M University and served as Director of Central Intelligence.

NANCY GRASMICK is the Maryland state superintendent of schools.

CHARLES HOLLIDAY JR. [NAE] is chairman of the Board and CEO of DuPont.

SHIRLEY ANN JACKSON [NAE] is president of Rensselaer Polytechnic Institute. She is the immediate past president of the American Association for the Advancement of Science and was chairman of the US Nuclear Regulatory Commission.

ANITA K. JONES [NAE] is the Lawrence R. Quarles Professor of Engineering and Applied Science at the University of Virginia. She served as director of defense research and engineering at the US Department of Defense and was vice-chair of the National Science Board.

JOSHUA LEDERBERG [NAS/IOM] is the Sackler Foundation Scholar at Rockefeller University in New York. He was a cowinner of the Nobel prize in physiology or medicine in 1958.

RICHARD LEVIN is president of Yale University and the Frederick William Beinecke Professor of Economics.

C. D. (DAN) MOTE JR. [NAE] is president of the University of Maryland and the Glenn L. Martin Institute Professor of Engineering.

CHERRY MURRAY [NAS/NAE] is the deputy director for science and technology at Lawrence Livermore National Laboratory. She was formerly the senior vice president at Bell Labs, Lucent Technologies.

PETER O'DONNELL JR. is president of the O'Donnell Foundation of Dallas, a private foundation that develops and funds model programs designed to strengthen engineering and science education and research.

LEE R. RAYMOND [NAE] is the chairman of the Board and CEO of Exxon Mobil Corporation.

ROBERT C. RICHARDSON [NAS] is the F. R. Newman Professor of Physics and the vice provost for research at Cornell University. He was a cowinner of the Nobel prize in physics in 1996.

P. ROY VAGELOS [NAS/IOM] is the retired chairman and CEO of Merck & Co., Inc.

CHARLES M. VEST [NAE] is president emeritus of MIT and a professor of mechanical engineering. He serves on the President's Council of Advisors on Science and Technology and is the immediate past chair of the Association of American Universities.

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FOR MORE INFORMATION

*This report was developed under the aegis of the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP), a joint committee of the three honorific academies—the National Academy of Sciences [NAS], the National Academy of Engineering [NAE], and the Institute of Medicine [IOM]. Its overall charge is to address cross-cutting issues in science and technology policy that affect the health of the national research enterprise.

More information, including the full body of the report, is available at COSEPUP's Web site, www.nationalacademies.org/cosepup.

NOTE

This report was reviewed in draft form by individuals chosen for their technical expertise, in accordance with procedures approved by the National Academies's Report Review Committee. For a list of those reviewers, refer to the full report.

EXECUTIVE SUMMARY

The United States takes deserved pride in the vitality of its economy, which forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities. That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Economic studies conducted even before the information-technology revolution have shown that as much as 85% of measured growth in US income per capita was due to technological change.[1]

Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing. This has been aptly referred to as "the Death of Distance."

CHARGE TO THE COMMITTEE

The National Academies was asked by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, with endorsement by Representative Sherwood Boehlert and Representative Bart Gordon of the House Committee on Science, to respond to the following questions:

> What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?

The National Academies created the Committee on Prospering in the Global Economy of the 21st Century to respond to this request. The charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen the quality of life in America—our prosperity, our health, and our security. The committee has been cautious in its analysis of information. The available information is only partly adequate for the committee's needs. In addition, the time allotted to develop the report (10 weeks from the time of the committee's first gathering to report release) limited the ability of the committee to conduct an exhaustive analysis. Even if unlimited time were available, definitive analyses on many issues are not possible given the uncertainties involved.[2]

This report reflects the consensus views and judgment of the committee members. Although the committee consists of leaders in academe, industry, and government—including several current and former industry chief executive officers, university presidents, researchers (including three Nobel prize winners), and former presidential appointees—the array of topics and policies covered is so broad that it was not possible to assemble a committee of 20 members with direct expertise in each relevant area. Because of those limitations, the committee has relied heavily on the judgment of many experts in the study's focus groups, additional consultations via e-mail and telephone with other experts, and an unusually large panel of reviewers. Although other solutions are undoubtedly possible, the committee believes that its recommendations, if implemented, will help the United States achieve prosperity in the 21st century.

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[1]For example, work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance," has been widely attributed to the effects of technological change.

[2]Since the prepublication version of the report was released in October, certain changes have been made to correct editorial and factual errors, add relevant examples and indicators, and ensure consistency among sections of the report. Although modifications have been made to the text, the recommendations remain unchanged, except for a few corrections, which have been footnoted.

FINDINGS

Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States. But we are worried about the future prosperity of the United States. Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all.

The committee found that multinational companies use criteria[3] such as the following in determining where to locate their facilities and the jobs that result:

- Cost of labor (professional and general workforce).
- Availability and cost of capital.
- Availability and quality of research and innovation talent.
- Availability of qualified workforce.
- Taxation environment.
- Indirect costs (litigation, employee benefits such as healthcare, pensions, vacations).
- Quality of research universities.
- Convenience of transportation and communication (including language).
- Fraction of national research and development supported by government.
- Legal-judicial system (business integrity, property rights, contract sanctity, patent protection).
- Current and potential growth of domestic market.
- Attractiveness as place to live for employees.
- Effectiveness of national economic system.

Although the US economy is doing well today, current trends in each of these areas indicate that the United States may not fare as well in the future without government intervention. This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of a low wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return to investors.

RECOMMENDATIONS

The committee reviewed hundreds of detailed suggestions—including various calls for novel and untested mechanisms—from other committees, from its focus groups, and from its own members. The challenge is immense, and the actions needed to respond are immense as well.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans, and responding to the nation's need for clean, affordable, and reliable energy. To address those challenges, the committee structured its ideas according to four basic recommendations that focus on the human, financial, and knowledge capital necessary for US prosperity.

The four recommendations focus on actions in K–12 education (*10,000 Teachers, 10 Million Minds*), research (*Sowing the Seeds*), higher education (*Best and Brightest*), and economic policy (*Incentives for Innovation*) that are set forth in the following sections. Also provided are a total of 20 implementation steps for reaching the goals set forth in the recommendations.

Some actions involve changes in the law. Others require financial support that would come from reallocation of existing funds or, if necessary, from new funds. Overall, the committee believes that the investments are modest relative to the magnitude of the return the nation can expect in the creation of new high-quality jobs and in responding to its energy needs.

The committee notes that the nation is unlikely to receive some sudden "wake-up" call; rather, the problem is one that is likely to evidence itself gradually over a surprisingly short period.

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[3] D.H. Dalton, M.G. Serapio, Jr., P.G. Yoshida. 1999. Globalizing Industrial Research and Development. US Department of Commerce, Technology Administration, Office of Technology Policy. Grant Gross. 2003, October 9. "CEOs defend moving jobs offshore at tech summit." InfoWorld. Mehlman, Bruce. 2003. Offshore Outsourcing and the Future of American Competitiveness. "High tech in China: is it a threat to Silicon Valley?" 2002, October 28. Business Week online. B. Callan, S. Costigan, K. Keller. 1997. Exporting U.S. High Tech: Facts and Fiction about the Globalization of Industrial R&D, Council on Foreign Relations, New York, NY.

10,000 TEACHERS, 10 MILLION MINDS, AND K–12 SCIENCE AND MATHEMATICS EDUCATION

RECOMMENDATION A: ***Increase America's talent pool by vastly improving K–12 science and mathematics education.***

Implementation Actions

The highest priority should be assigned to the following actions and programs. All should be subjected to continuing evaluation and refinement as they are implemented.

Action A-1: Annually recruit 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds. Attract 10,000 of America's brightest students to the teaching profession every year, each of whom can have an impact on 1,000 students over the course of their careers. The program would award competitive 4-year scholarships for students to obtain bachelor's degrees in the physical or life sciences, engineering, or mathematics with concurrent certification as K–12 science and mathematics teachers. The merit-based scholarships would provide up to \$20,000 a year for 4 years for qualified educational expenses, including tuition and fees, and require a commitment to 5 years of service in public K–12 schools. A \$10,000 annual bonus would go to participating teachers in underserved schools in inner cities and rural areas. To provide the highest-quality education for undergraduates who want to become teachers, it would be important to award matching grants, on a one-to-one basis, of \$1 million a year for up to 5 years, to as many as 100 universities and colleges to encourage them to establish integrated 4-year undergraduate programs leading to bachelor's degrees in the physical and life sciences, mathematics, computer sciences, or engineering *with teacher certification*. The models for this action are UTeach at the University of Texas and California Teach at the University of California.

Action A-2: Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master's programs, and in Advanced Placement (AP) and International Baccalaureate (IB) training programs. Use proven models to strengthen the skills (and compensation, which is based on education and skill level) of 250,000 *current* K–12 teachers.

- *Summer institutes:* Provide matching grants to state and regional 1- to 2-week summer institutes to upgrade the skills and state-of-the-art knowledge of as many as 50,000 practicing teachers each summer. The material covered would allow teachers to keep current with recent developments in science, mathematics, and technology and allow for the exchange of best teaching practices. The Merck Institute for Science Education is one model for this action.

- *Science and mathematics master's programs:* Provide grants to research universities to offer, over 5 years, 50,000 current middle school and high school science, mathematics, and technology teachers (with or without undergraduate science, mathematics, or engineering degrees) 2-year, part-time master's degree programs that focus on rigorous science and mathematics content and pedagogy. The model for this action is the University of Pennsylvania Science Teachers Institute.

- *AP, IB, and pre-AP or pre-IB training:* Train an additional 70,000 AP or IB and 80,000 pre-AP or pre-IB instructors to teach advanced courses in science and mathematics. Assuming satisfactory performance, teachers may receive incentive payments of \$1,800 per year, as well as \$100 for each student who passes an AP or IB exam in mathematics or science. There are two models for this program: the Advanced Placement Incentive Program and Laying the Foundation, a pre-AP program.

- *K–12 curriculum materials modeled on a world-class standard:* Foster high-quality teaching with world-class curricula, standards, and assessments of student learning. Convene a national panel to collect, evaluate, and develop rigorous K–12 materials that would be available free of charge as a *voluntary* national curriculum. The model for this action is the Project Lead the Way pre-engineering courseware.

Action A-3: Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass AP and IB science and mathematics courses. Create opportunities and incentives for middle school and high school students to pursue advanced work in science and mathematics. By 2010, increase the number of students who take at least one AP or IB mathematics or science exam to 1.5 million, and set a goal of tripling the number who pass those tests to 700,000.[4] Student incentives for success would include 50% examination fee rebates and $100 mini-scholarships for each passing score on an AP or IB science or mathematics examination.

Although not included among its implementation actions, the committee also finds attractive the expansion of two approaches to improving K–12 science and mathematics education that are already in use:

- *Statewide specialty high schools:* Specialty secondary education can foster leaders in science, technology, and mathematics. Specialty schools immerse students in high-quality science, technology, and mathematics education; serve as a mechanism to test teaching materials; provide a training ground for K–12 teachers; and provide the resources and staff for summer programs that introduce students to science and mathematics.

- *Inquiry-based learning:* Summer internships and research opportunities provide especially valuable laboratory experience for both middle school and high school students.

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[4]This sentence was incorrectly phrased in the original October 12, 2005 edition of the Executive Summary and has now been corrected.

[5]The funds may come from anywhere in government, not just other research funds.

SOWING THE SEEDS THROUGH SCIENCE AND ENGINEERING RESEARCH

RECOMMENDATION B: ***Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.***

Implementation Actions

Action B-1: Increase the federal investment in long-term basic research by 10% each year over the next 7 years through reallocation of existing funds[5] or, if necessary, through the investment of new funds. Special attention should go to the physical sciences, engineering, mathematics, and information sciences and to Department of Defense (DoD) basic-research funding. This special attention does not mean that there should be a disinvestment in such important fields as the life sciences or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to US prosperity. Increasingly, the most significant new scientific and engineering advances are formed to cut across several disciplines. This investment should be evaluated regularly to realign the research portfolio to satisfy emerging needs and promises—unsuccessful projects and venues of research should be replaced with research projects and venues that have greater potential.

Action B-2: Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of the nation's most outstanding *early-career* researchers. The grants would be made through existing federal research agencies—the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Energy (DoE), DoD, and the National Aeronautics and Space Administration (NASA)—to underwrite new research opportunities at universities and government laboratories.

Action B-3: Institute a National Coordination Office for Advanced Research Instrumentation and Facilities to manage a fund of $500 million in incremental funds per year over the next 5 years—through reallocation of existing funds or, if necessary, through the investment of new funds—to ensure that universities and government laboratories create and maintain the facilities, instrumentation, and equipment needed for leading-edge scientific discovery and technological development. Universities and national laboratories would compete annually for these funds.

Action B-4: Allocate at least 8% of the budgets of federal research agencies to discretionary funding that would be managed by technical program managers in the agencies and be focused on catalyzing high-risk, high-payoff research of the type that often suffers in today's increasingly risk-averse environment.

Action B-5: Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E).[6] The director of ARPA-E would report to the under secretary for science and would be charged with sponsoring specific research and development programs to meet the nation's long-term energy challenges. The new agency would support creative "out-of-the-box" transformational generic energy research that industry by itself cannot or will not support and in which risk may be high but success would provide dramatic benefits for the nation. This would accelerate the process by which knowledge obtained through research is transformed to create jobs and address environmental, energy, and security issues. ARPA-E would be based on the historically successful DARPA model and would be designed as a lean and agile organization with a great deal of independence that can start and stop targeted programs on the basis of performance and do so in a timely manner. The agency would itself perform no research or transitional effort but would fund such work conducted by universities, startups, established firms, and others. Its staff would turn over approximately every 4 years. Although the agency would be focused on specific energy issues, it is expected that its work (like that of DARPA or NIH) will have important spinoff benefits, including aiding in the education of the next generation of researchers. Funding for ARPA-E would start at $300 million the first year and increase to $1 billion per year over 5-6 years, at which point the program's effectiveness would be evaluated and any appropriate actions taken.

Action B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest. Existing presidential awards recognize lifetime achievements or promising young scholars, but the proposed new awards would identify and recognize persons who develop unique scientific and engineering innovations in the national interest at the time they occur.

[6]One committee member, Lee Raymond, does not support this action item. He does not believe that ARPA-E is necessary as energy research is already well funded by the federal government, along with formidable funding of energy research by the private sector. Also, ARPA-E would, in his view, put the federal government in the business of picking "winning energy technologies"—a role best left to the private sector.

BEST AND BRIGHTEST IN SCIENCE AND ENGINEERING HIGHER EDUCATION

RECOMMENDATION C: ***Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.***

Implementation Actions

Action C-1: Increase the number and proportion of US citizens who earn bachelor's degree in the physical sciences, the life sciences, engineering, and mathematics by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens attending US institutions. The Undergraduate Scholar Awards in Science, Technology, Engineering, and Mathematics (USA-STEM) would be distributed to states on the basis of the size of their congressional delegations and awarded on the basis of national examinations. An award would provide up to $20,000 annually for tuition and fees.

Action C-2: Increase the number of US citizens pursuing graduate study in "areas of national need" by funding 5,000 new graduate fellowships each year. NSF should administer the program and draw on the advice of other federal research agencies to define national needs. The focus on national needs is important both to ensure an adequate supply of doctoral scientists and engineers and to ensure that there are appropriate employment opportunities for students once they receive their degrees. Portable fellowships would provide a stipend of $30,000[7] annually directly to students, who would choose where to pursue graduate studies instead of being required to follow faculty research grants, and up to $20,000 annually for tuition and fees.

[7]An incorrect number was provided for the graduate student stipend in the original October 12, 2005 edition of the Executive Summary and has now been corrected.

Action C-3: Provide a federal tax credit to encourage employers to make continuing education available (either internally or though colleges and universities) to practicing scientists and engineers. These incentives would promote career-long learning to keep the workforce productive in an environment of rapidly evolving scientific and engineering discoveries and technological advances and would allow for retraining to meet new demands of the job market.

Action C-4: Continue to improve visa processing for international students and scholars to provide less complex procedures and continue to make improvements on such issues as visa categories and duration, travel for scientific meetings, the technology alert list, reciprocity agreements, and changes in status.

Action C-5: Provide a 1-year automatic visa extension to international students who receive doctorates or the equivalent in science, technology, engineering, mathematics, or other fields of national need at qualified US institutions to remain in the United States to seek employment. If these students are offered jobs by US-based employers and pass a security screening test, they should be provided automatic work permits and expedited residence status. If students are unable to obtain employment within 1 year, their visas would expire.

Action C-6: Institute a new skills-based, preferential immigration option. Doctoral-level education and science and engineering skills would substantially raise an applicant's chances and priority in obtaining US citizenship. In the interim, the number of H-1B visas should be increase by 10,000, and the additional visas should be available for industry to hire science and engineering applicants with doctorates from US universities.[8]

[8]Since the report was released, the committee has learned that the Consolidated Appropriations Act of 2005, signed into law on December 8, 2004, exempts individuals that have received a master's or higher education degree from a US university from the statutory cap (up to 20,000). The bill also raised the H-1B fee and allocated funds to train American workers. The committee believes that this provision is sufficient to respond to its recommendation—even though the 10,000 additional visas recommended is specifically for science and engineering doctoral candidates from US universities, which is a narrower subgroup.

Action C-7: Reform the current system of "deemed exports". The new system should provide international students and researchers engaged in fundamental research in the United States with access to information and research equipment in US industrial, academic, and national laboratories comparable with the access provided to US citizens and permanent residents in a similar status. It would, of course, exclude information and facilities restricted under national-security regulations. In addition, the effect of deemed-exports[9] regulations on the education and fundamental research work of international students and scholars should be limited by removing from the deemed-exports technology list all technology items (information and equipment) that are available for purchase on the overseas open market from foreign or US companies or that have manuals that are available in the public domain, in libraries, over the Internet, or from manufacturers.

[9]The controls governed by the Export Administration Act and its implementing regulations extend to the transfer of technology. Technology includes "specific information necessary for the 'development,' 'production,' or 'use' of a product". Providing information that is subject to export controls—for example, about some kinds of computer hardware—to a foreign national within the United States may be "deemed" an export, and that transfer requires an export license. The primary responsibility for administering controls on deemed exports lies with the Department of Commerce, but other agencies have regulatory authority as well.

INCENTIVES FOR INNOVATION

Recommendation D: Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.

Implementation Actions

Action D-1: Enhance intellectual-property protection for the 21st-century global economy to ensure that systems for protecting patents and other forms of intellectual property underlie the emerging knowledge economy but allow research to enhance innovation. The patent system requires reform of four specific kinds:

- Provide the US Patent and Trademark Office with sufficient resources to make intellectual-property protection more timely, predictable, and effective.

- Reconfigure the US patent system by switching to a "first-inventor-to-file" system and by instituting administrative review *after* a patent is granted. Those reforms would bring the US system into alignment with patent systems in Europe and Japan.

- Shield research uses of patented inventions from infringement liability. One recent court decision could jeopardize the long-assumed ability of academic researchers to use patented inventions for research.

- Change intellectual-property laws that act as barriers to innovation in specific industries, such as those related to data exclusivity (in pharmaceuticals) and those that increase the volume and unpredictability of litigation (especially in information-technology industries).

Action D-2: Enact a stronger research and development tax credit to encourage private investment in innovation. The current Research and Experimentation Tax Credit goes to companies that *increase* their research and development spending above a base amount calculated from their spending in prior years. Congress and the

Administration should make the credit permanent,[10] and it should be increased from 20% to 40% of the qualifying increase so that the US tax credit is competitive with those of other countries. The credit should be extended to companies that have consistently spent large amounts on research and development so that they will not be subject to the current *de facto* penalties for having previously invested in research and development.

Action D-3: Provide tax incentives for US-based innovation. Many policies and programs affect innovation and the nation's ability to profit from it. It was not possible for the committee to conduct an exhaustive examination, but alternatives to current economic policies should be examined and, if deemed beneficial to the United States, pursued. These alternatives could include changes in overall corporate tax rates and special tax provisions providing the purchase of high-technology research and manufacturing equipment, treatment of capital gains, and incentives for long-term investments in innovation. The Council of Economic Advisers and the Congressional Budget Office should conduct a comprehensive analysis to examine how the United States compares with other nations as a location for innovation and related activities with a view to ensuring that the United States is one of the most attractive places in the world for long-term innovation-related investment and the jobs resulting from that investment. From a tax standpoint, that is not now the case.

Action D-4: Ensure ubiquitous broadband Internet access. Several nations are well ahead of the United States in providing broadband access for home, school, and business. That capability can be expected to do as much to drive innovation, the economy, and job creation in the 21st century as did access to the telephone, interstate highways, and air travel in the 20th century. Congress and the Administration should take action—mainly in the regulatory arena and in spectrum management—to ensure widespread affordable broadband access in the very near future.

[10]The previous R&D tax credit expired in December 2005.

CONCLUSION

The committee believes that its recommendations and the actions proposed to implement them merit serious consideration if we are to ensure that our nation continues to enjoy the jobs, security, and high standard of living that this and previous generations worked so hard to create. Although the committee was asked only to recommend actions that can be taken by the federal government, it is clear that related actions at the state and local levels are equally important for US prosperity, as are actions taken by each American family. The United States faces an enormous challenge because of the disparity it faces in labor costs. Science and technology provide the opportunity to overcome that disparity by creating scientists and engineers with the ability to create entire new industries—much as has been done in the past.

It is easy to be complacent about US competitiveness and preeminence in science and technology. We have led the world for decades, and we continue to do so in many research fields today. But the world is changing rapidly, and our advantages are no longer unique. Some will argue that this is a problem for market forces to resolve—but that is exactly the concern. Market forces are *already at work* moving jobs to countries with less costly, often better educated, highly motivated work forces and more friendly tax policies.

Without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position. For the first time in generations, the nation's children could face poorer prospects than their parents and grandparents did. We owe our current prosperity, security, and good health to the investments of past generations, and we are obliged to renew those commitments in education, research, and innovation policies to ensure that the American people continue to benefit from the remarkable opportunities provided by the rapid development of the global economy and its not inconsiderable underpinning in science and technology.

SOME COMPETITIVENESS INDICATORS

US ECONOMY

- The United States is today a net importer of *high-technology* products. Its trade balance in high-technology manufactured goods shifted from *plus* $54 billion in 1990 to *negative* $50 billion in 2001.[1]

- In one recent period, low-wage employers, such as Wal-Mart (now the nation's largest employer) and McDonald's, created 44% of the new jobs while high-wage employers created only 29% of the new jobs.[2]

- The United States is one of the few countries in which industry plays a major role in providing health care for its employees and their families. Starbucks spends more on healthcare than on coffee. General Motors spends more on health care than on steel.[3]

- US scheduled airlines currently outsource portions of their aircraft maintenance to China and El Salvador.[4]

- IBM recently sold its personal computer business to an entity in China.[5]

- Ford and General Motors both have junk bond ratings.[6]

- It has been estimated that within a decade nearly 80% of the world's middle-income consumers would live in nations outside the currently industrialized world. China alone could have 595 million middle-income consumers and 82 million upper-middle-income consumers. The total population of the United States is currently 300 million and is projected to be 315 million in a decade.[7]

- Some economists estimate that about half of US economic growth since World War II has been the result of technological innovation.[8]

- In 2005, American investors put more new money in foreign stock funds than in domestic stock portfolios.[9]

COMPARATIVE ECONOMICS

- Chemical companies closed 70 facilities in the United States in 2004 and tagged 40 more for shutdown. Of 120 chemical plants being built around the world with price tags of $1 billion or more, one is in the United States and 50 are in China. No new refineries have been built in the United States since 1976.[10]

- The United States is said to have 7 million illegal immigrants,[11] but under the law the number of visas set aside for "highly qualified foreign workers," many of whom contribute significantly to the nation's innovations, dropped to 65,000 a year from its 195,000 peak.[12]

- When asked in Spring 2005 what is the most attractive place in the world in which to "lead a good life", respondents in only one (India) of the 16 countries polled indicated the United States.[13]

- A company can hire nine factory workers in Mexico for the cost of one in America. A company can hire eight young professional engineers in India for the cost of one in America.[14]

- The share of leading-edge semiconductor manufacturing capacity owned or partly owned by US companies today is half what it was as recently as 2001.[15]

- During 2004, China overtook the United States to become the leading exporter of information-technology products, according to the OECD.[16]

- The United States ranks only 12th among OECD countries in the number of broadband connections per 100 inhabitants.[17]

K-12 EDUCATION

- Fewer than one-third of US 4th-grade and 8th-grade students performed at or above a level called "proficient" in mathematics; "proficiency" was considered the ability to exhibit competence with challenging subject matter. Alarmingly, about one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform even basic mathematical computations.[18]

- In 1999, 68% of US 8th grade students received instruction from a mathematics teacher who did not hold a degree or certification in mathematics.[19]

- In 2000, 93% of students in grades 5-9 were taught physical science by a teacher lacking a major or certification in the physical sciences (chemistry, geology, general science, or physics).[20]

- In 1995 (the most recent data available), US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science.[21]

- US 15-year-olds ranked 24th out of 40 countries that participated in a 2003 administration of the Program for International Student Assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real-world problems.[22]

- According to a recent survey, 86% of US voters believe that the United States must increase the number of workers with a background in science and mathematics or America's ability to compete in the global economy will be diminished.[23]

- American youth spend more time watching television[24] than in school.[25]

- Because the United States does not have a set of national curricula, changing K-12 education is challenging, given that there are almost 15,000 school systems in the United States and the average district has only about 6 schools.[26]

HIGHER EDUCATION

- In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore 67%. In the United States, the corresponding figure is 15%.[27]

- Some 34% percent of doctoral degrees in natural sciences (including the physical, biological, earth, ocean, and atmospheric sciences) and 56% of engineering PhDs in the United States are awarded to foreign-born students.[28]

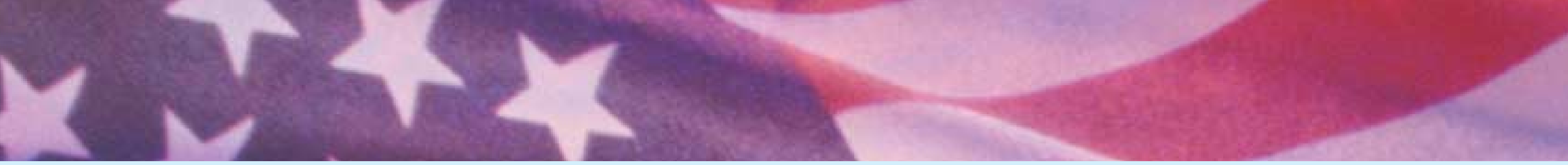
- In the US science and technology workforce in 2000, 38% of PhDs were foreign-born. [29]

- Estimates of the number of engineers, computer scientists, and information technology students who obtain 2-, 3-, or 4-year degrees vary. One estimate is that in 2004, China graduated about 350,000 engineers, computer scientists, and information technologists with 4-year degrees, while the United States graduated about 140,000. China also graduated about 290,000 with 3-year degrees in these same fields, while the United States graduated about 85,000 with 2- or 3-year degrees.[30] Over the past 3 years alone, both China[31] and India[32] have doubled their production of 3- and 4-year degrees in these fields, while the US[33] production of engineers is stagnant and the rate of production of computer scientists and information technologists doubled.

- About one-third of US students intending to major in engineering switch majors before graduating.[34]

- There were almost twice as many US physics bachelor's degrees awarded as in 1956, the last graduating class before Sputnik than in 2004.[35]

- More S&P 500 CEOs obtained their undergraduate degrees in engineering than in any other field.[36]



RESEARCH

- In 2001 (the most recent year for which data are available), US industry spent more on tort litigation than on research and development.[37]
- In 2005, only four American companies ranked among the top 10 corporate recipients of patents granted by the *United States* Patent and Trademark Office.[38]
- Beginning in 2007, the most capable high-energy particle accelerator on Earth will, for the first time, reside outside the United States.[39]
- Federal funding of research in the physical sciences, as a percentage of GDP, was 45% less in FY 2004 than in FY 1976.[40] The amount invested annually by the US federal government in research in the physical sciences, mathematics, and engineering combined equals the annual increase in US health care costs incurred every 20 days.[41]

PERSPECTIVES

- "We go where the smart people are. Now our business operations are two-thirds in the U.S. and one-third overseas. But that ratio will flip over the next 10 years." –Intel spokesman Howard High[42]
- "If we don't step up to the challenge of finding and supporting the best teachers, we'll undermine everything else we are trying to do to improve our schools."—Louis V. Gerstner, Jr., Former Chairman, IBM[43]
- "If you want good manufacturing jobs, one thing you could do is graduate more engineers. We had more sports exercise majors graduate than electrical engineering grads last year." —Jeffrey R. Immelt, Chairman and Chief Executive Office, General Electric[44]
- "If I take the revenue in January and look again in December of that year 90% of my December revenue comes from products which were not there in January." – Craig Barrett, Chairman of the Intel Corporation[45]
- "When I compare our high schools to what I see when I'm traveling abroad, I am terrified for our workforce of tomorrow." –Bill Gates, Chairman and Chief Software Architect of Microsoft Corporation[46]
- "Where once nations measured their strength by the size of their armies and arsenals, in the world of the future knowledge will matter most." –President Bill Clinton [47]
- "Science and technology have never been more essential to the defense of the nation and the health of our economy."—President George W. Bush[48]

NOTES for SOME COMPETITIVENESS INDICATORS and PERSPECTIVES:

[1]For 2001, the dollar value of high-technology imports was $561 billion; the value of high-technology exports was $511 billion. See National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA. National Science Foundation. Appendix Table 6-01. Page A6-5 provides the export numbers for 1990 and 2001 and page A6-6 has the import numbers.

[2]Steve Roach. More Jobs, Worse Work. New York Times. July 22, 2004.

[3]Chris Noon. 2005. "Starbuck's Schultz Bemoans Health Care Costs." Forbes.com, September 19.Available at:http://www.forbes.com/facesinthenews/2005/09/15/starbuckshealthcarebenefitscx_cn_0915autofacescan01.html?partner=yahooti; Ron Scherer. 2005. "Rising Benefits Burden." Christian Science Monitor, June 9. Available at: http://www.csmonitor.com/2005/0609/p01s01-usec.html.

[4]Sara Kehaulani Goo. Airlines Outsource Upkeep. Washington Post. August 21, 2005. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2005/08/20/AR2005082000979.html. Sara Kehaulani Goo. Two-Way Traffic in Airplane Repair. Washington Post, June 1, 2004. Available at http://www.washingtonpost.com/wp-dyn/articles/A5138-2004 May31.html.

[5]Michael Kanellos. 2004. "IBM Sells PC Group to Lenovo." News.com. December 8. Available at: http://news.com.com/IBM+sells+PC+group+to+Lenovo/2100-1042_3-5482284.html.

[6]http://www.nytimes.com/2005/05/05/business/05cnd-auto.html?ex=1137128400 &en=ac63687768634c6d&ei=5070.

[7]For China, see Paul A. Laudicina, 2005. World Out of Balance: Navigating Global Risks to Seize Competitive Advantage. New York: McGraw Hill, p. 76. For the United States, see US Census Bureau. US. Population Clock. Available at www.census.gov for current population and for the projected population, see Population Projections Program, Population Division, U.S. Census Bureau. Population Projections of the United States by Age, Sex, Race, Hispanic Origin, and Nativity: 1999 to 2100. Washington, D.C. January 13, 2000. Available at: http://www.census.gov/population/www/projections/natsum-T3.html.

[8]Michael J. Boskin and Lawrence J. Lau. 1992. Capital, Technology, and Economic Growth. In Nathan Rosenberg, Ralph Landau, and David C. Mowery, eds. Technology and the Wealth of Nations: Stanford University Press: Stanford, CA.

[9]Paul J. Lim. Looking Ahead Means Looking Abroad. New York Times. January 8th 2006.

[10]Michael Arndt. 2005. "No Longer the Lab of the World: U.S. Chemical Plants are Closing in Droves as Production Heads Abroad." BusinessWeek, May 2. Available at: http://www.businessweek.com/magazine/content/05_18/b3931106.htm and http://www.usnews.com/usnews/biztech/articles/051010/10energy.htm.

[11]As of 2000, the unauthorized resident population in the United States was 7 million. See US Citizenship and Immigration Services. 2003. "Executive Summary: Estimates of the Unauthorized Immigrant Population Residing in the United States: 1990 to 2000." January 31. Available at: http://uscis.gov/graphics/shared/statistics/publications/2000ExecSumm.pdf.

[12]Section 214(g) of the Immigration and Nationality Act (Act) sets an annual limit on the number of aliens that can receive H-1B status in a fiscal year. For FY2000 the limit was set at 115,000. The American Competitiveness in the Twenty-First Century Act increased the annual limit to 195,000 for 2001, 2002, and 2003. After that date the cap reverts back to 65,000. H-1B visas allow employers to have access to highly educated foreign professionals who have experience in specialized fields and who have at least a bachelor's degree or the equivalent. The cap does not apply to educational institutions. In November 2004, Congress created an exemption for 20,000 foreign nationals earning advanced degrees from US universities. See Immigration and Nationality Act Section 101(a)(15)(h)(1)(b). See US Citizenship and Immigration Services. 2005. "Public Notice: "USCIS Announces Update Regarding New H-1B Exemptions" July 12. Available at: http://uscis.gov/graphics/publicaffairs/newsrels/H1B_06Cap_011806PR.pdf. and US Citizenship and Immigration Services. 2000. "Questions and Answers: Changes to the H-1B Program" November 21. Available at: http://uscis.gov/graphics/publicaffairs/questsans/H1BChang.htm.

[13]Pew Research Center. 2005 "U.S. Image Up Slightly, But Still Negative, American Character Gets Mixed Reviews" Pew Global Attitudes Project. Washington, DC. Available at: http://pewglobal.org/reports/display.php?ReportID=247 The interview asked nearly 17,000 people the question: "Suppose a young person who wanted to leave this country asked you to recommend where to go to lead a good life–what country would you recommend?" Except for respondents in India, Poland, and Canada, no more than one-tenth of the people in the other nations said they would recommend the United States. Canada and Australia won the popularity contest.

[14]United States Bureau of Labor Statistics. 2005. International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing, 2004. November 18. Available at: ftp://ftp.bls.gov/pub/news.release/History/ichcc.11182005.news.

[15]Semiconductor Industry Association. 2005. "Choosing to Compete." December 12. Available at: http://www.sia-online.org/downloads/FAD%20'05%20-%20Scalise%20Presentation.pdf.

[16]OECD. 2005. "China Overtakes U.S. As World's Leading Exporter of Information Technology Goods." December 12. Available at: http://www.oecd.org/document/60/0,2340,en_2649_201185_35834236_1_1_1_1,00.html. The main categories included in OECD's definition of ICT (information and communications technology) goods are electronic components, computers and related equipment, audio and video equipment, and telecommunication equipment.

[17]OECD. 2005. "OECD Broadband Statistics, June 2005." October 20. Available at: http://www.oecd.org/document/16/0,2340,en_2649_201185_35526608_1_1_1_1,00.html#data2004.

[18]National Center for Education Statistics. 2006. "The Nation's Report Card: Mathematics 2005." See http://nces.ed.gov/nationsreportcard/pdf/main2005/2006453.pdf.

[19]National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. Chapter 1.

[20]National Center for Education Statistics. 2004. Schools and Staffing Survey, "Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 to 1999-2000 (Revised)," p. 10. See http://nces.ed.gov/pubs2002/2002603.pdf.

[21]National Center for Education Statistics. 1999. Highlights from TIMSS http://nces.ed.gov/pubs99/1999081.pdf.

[22]National Center for Education Statistics.2005. "International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results from the U.S. Perspective," pp. 15 and 29. See http://nces.ed.gov/pubs2005/2005003.pdf.

[23]The Business Roundtable. 2006. "Innovation and U.S. Competitiveness: Addressing the Talent Gap. Public Opinion Research." January 12. Available at: http://www.businessroundtable.org/pdf/20060112Two-pager.pdf.

[24]American Academy of Pediatrics. "Television—How it Affects Children." Available at http://www.aap.org/pubed/ZZZGF8VOQ7C.htm?&sub_cat=1. The American Academy of Pediatrics reports that "Children in the United States watch about 4 hours of TV every day"; this works out to be 1460 hours per year.

[25]National Center for Education Statistics. 2005. The Condition of Education. Table 26-2 Average Number of Instructional Hours Per Year Spent in Public School, By Age or Grade of Student and Country: 2000 and 2001. Available at http://nces.ed.gov/programs/coe/2005/section4/table.asp? tableID=284. NCES reports that in 2000 US 15-year-olds spent 990 hours in school, during the same year 4th graders spent 1040 hours.

[26]National Center for Education Statistic (2006), "Public Elementary and Secondary Students, Staff, Schools, and School Districts: School Year 2003–04". See http://nces.ed.gov/pubs2006/2006307.pdf.

[27]Analysis conducted by the Association of American Universities. 2006. National Defense Education and Innovation Initiative. Based on data in National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. Appendix Table 2-33. For countries with both short and long degrees, the ratios are calculated with both short and long degrees as the numerator.

[28]National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. Chapter 2, Figure 2-23.

[29]National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation.

[30]G. Gereffi and V. Wadhwa. 2005. Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India. http://memp.pratt.duke.edu/downloads/duke_outsourcing_2005.pdf.

[31]Ministry of Science and Technology (MOST). 2004. Chinese Statistical Yearbook 2004. People's Republic of China, Chapter 21, Table 21-11. Available at http://www.stats.gov.cn/english/statisticaldata/yearlydata/yb2004-e/indexeh.htm. The extent to which engineering degrees from China are comparable to those from the United States is uncertain.

[32]National Association of Software and Service Companies. 2005. Strategic Review 2005., India. Chapter 6. Sustaining the India Advantage. Available at http://www.nasscom.org/strategic2005.asp.

[33]National Center for Education Statistics. 2004. Digest of Education Statistics 2004. Institute of Education Sciences, Department of Education, Washington DC, Table 250. Available at http://nces.ed.gov/programs/digest/d04/tables/dt04_250.asp.

[34]Myles Boylan. 2004. Assessing Changes in Student Interest in Engineering Careers Over the Last Decade. CASEE, National Academy of Engineering. Available at http://www.nae.edu/NAE/caseecomnew.nsf/ weblinks/NFOY-6GHJ7B/$file/Engineering%20Interest%20-%20HS%20through%20College_V21.pdf; Clifford Adelman. 1998. Women and Men on the Engineering Path: A Model for Analysis of Undergraduate Careers. Washington DC: US Department of Education. http://www.nae.edu/nae/diversitycom.nsf/98b72da8aad70f1785256da20053deaf/85256cfb00484b5c85256da000002f83/$FILE/Adelman_Women_and_Men_of_the_Engineering_Path.pdf). According to this Department of Education analysis, the majority of students who switch from engineering majors complete a major in business or other non-science and engineering fields.

[35]National Center for Education Statistics Digest of Education Statistics. The American Institute of Physics Statistical Research Center.

[36]Spencer Stuart. 2005. "2004 CEO Study: A Statistical Snapshot of Leading CEOs." Available at: http://content.spencerstuart.com/sswebsite/pdf/lib/Statistical_Snapshot_of_Leading_CEOs_relB3.pdf#search='ceo%20educational%20background'.

[37]US research and development spending in 2001 was $273.6 billion, of which industry performed $194 billion and funded about $184 billion. National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. One estimate of tort litigation costs in the United States was $205 billion in 2001. Jeremey A. Leonard. 2003. "How Structural Costs Imposed on U.S. Manufacturers Harm Workers and Threaten Competitiveness." Prepared for the Manufacturing Institute of the National Association of Manufacturers. Availbale at: http://www.nam.org/s_nam/bin.asp?CID=216&DID=227525&DOC=FILE.PDF.

[38]US Patent and Trademark Office.2006. USPTO Annual List of Top 10 Organizations Receiving Most U.S. Patents. January 10, 2006. See http://www. uspto.gov/web/offices/com/speeches/06-03.htm

[39]CERN. Internet Homepage. http://public.web.cern.ch/Public/Welcome.html.

[40]American Association for the Advancement of Science. 2004. "Trends in Federal Research by Discipline, FY 1976-2004." October. Available at: http://www.aaas.org/spp/rd/disc04tb.pdf and http://www.aaas.org/spp/rd/discip04c.pdf.

[41]Centers for Medicare and Medicaid Services. 2005. National Heath Expenditures. Available at: http://www.cms.hhs.gov/NationalHealthExpendData/downloads/tables.pdf.

[42]In: Wallace, Kathryn. 2005. "America's Brain Drain Crisis Why Our Best Scientists are Disappearing, and What's Really at Stake." Readers Digest. December.

[43]Louis V. Gerstner, Jr. Former Chairman, IBM In The Teaching Commission. 2004. Teaching at Risk: A Call to Action. New York: City University of New York. See www.theteachingcommission.org.

[44]Remarks by Jeffrey R. Immelt to Economic Club of Washington as reported in Neil Irwin. 2006. "US Needs More Engineers, GE Chief Says." Washington Post. January 23, 2006.

[45]Craig Barrett. 2006. Comments at public briefing on the release of The Gathering Storm report. October 12, 2005. See http://www.nationalacademies.org/morenews/20051012.html.

[46]Bill Gates. 2005. Speech to the National Education Summit on High Schools. February 26. Available at: http://www.gatesfoundation.org/MediaCenter/Speeches/BillgSpeeches/BGSpeechNGA-050226.htm.

[47]William Jefferson Clinton "Commencement Address at Morgan State University in Baltimore, Maryland." May 18, 1997 Government Printing Office. 1997 Public Papers of the Presidents of the United States, Books I and II. Available at: http://www.gpoaccess.gov/pubpapers/wjclinton.html.

[48]Remarks by President George W. Bush in meeting with High-Tech Leaders. March 28, 2001. Available at: http://www.whitehouse.gov/news/releases/ 2001/03/20010328-2.html.

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Appendices

Appendix C

Montgomery County Public Schools
2005-2006 Information Technology Course Data

Montgomery County Public Schools
2005-2006 Information Technology Course Data

Course Number	Course Title	Gender	Number of Students	%	W	%	AA	%	H	%	IA	%	A	%	ESOL	%	FARMS	%	504 PLAN	%	SEDS	%	Total Enrollment
2964	Discovering	Female	102	23.6%	44	10.2%	22	5.1%	13	3.0%	0	0.0%	23	5.3%	2	0.5%	7	1.6%	2	0.5%	2	0.5%	
	Programming	Male	330	76.4%	180	41.7%	58	13.4%	39	9.0%	1	0.2%	52	12.0%	9	2.1%	25	5.8%	11	2.5%	27	6.3%	
	Concepts A			100.0%		51.9%		18.5%		12.0%		0.2%		17.4%		2.5%		7.4%		3.0%		6.7%	**432**
2967	Discovering	Female	84	21.0%	37	9.3%	16	4.0%	10	2.5%	0	0.0%	21	5.3%	2	0.5%	7	1.8%	2	0.5%	0	0.0%	
	Programming	Male	316	79.0%	171	42.8%	57	14.3%	35	8.8%	1	0.3%	52	13.0%	10	2.5%	23	5.8%	11	2.8%	26	6.5%	
	Concepts B			100.0%		52.0%		18.3%		11.3%		0.3%		18.3%		3.0%		7.5%		3.3%		6.5%	**400**
2989	Computer	Female	294	26.4%	112	10.0%	29	2.6%	36	3.2%	0	0.0%	117	10.5%	5	0.4%	24	2.2%	2	0.2%	4	0.4%	
	Programming 1	Male	821	73.6%	433	38.8%	79	7.1%	69	6.2%	0	0.0%	240	21.5%	21	1.9%	52	4.7%	19	1.7%	46	4.1%	
	A/B			100.0%		48.9%		9.7%		9.4%		0.0%		32.0%		2.3%		6.8%		1.9%		4.5%	**1115**
2990	Computer	Female	281	26.0%	110	10.2%	24	2.2%	29	2.7%	0	0.0%	118	10.9%	5	0.5%	21	1.9%	2	0.2%	5	0.5%	
	Programming 1	Male	800	74.0%	425	39.3%	82	7.6%	69	6.4%	0	0.0%	224	20.7%	30	2.8%	52	4.8%	17	1.6%	45	4.2%	
	A/B			100.0%		49.5%		9.8%		9.1%		0.0%		31.6%		3.2%		6.8%		1.8%		4.6%	**1081**
4200	Computer	Female	15	18.5%	4	4.9%	2	2.5%	3	3.7%	1	1.2%	5	6.2%	0	0.0%	1	1.2%	0	0.0%	0	0.0%	
	Programming 1	Male	66	81.5%	30	37.0%	10	12.3%	6	7.4%	0	0.0%	20	24.7%	1	1.2%	5	6.2%	0	0.0%	4	4.9%	
	A/B			100.0%		42.0%		14.8%		11.1%		1.2%		30.9%		1.2%		7.4%		0.0%		4.9%	**81**
4201	Computer	Female	2	6.5%	0	0.0%	1	3.2%	0	16.1%	0	0.0%	1	3.2%	1	3.2%	0	0.0%	0	0.0%	0	0.0%	
	Programming 1	Male	29	93.5%	15	48.4%	2	6.5%	5	16.1%	0	0.0%	7	22.6%	1	3.2%	1	3.2%	0	0.0%	4	12.9%	
	A/B			100.0%		48.4%		9.7%		32.3%		0.0%		25.8%		6.5%		3.2%		0.0%		12.9%	**31**
2901	Computer	Female	50	13.0%	15	3.9%	2	0.5%	2	0.5%	0	0.0%	31	8.1%	1	0.3%	2	0.5%	0	0.0%	0	0.0%	
	Programming 2,	Male	334	87.0%	199	51.8%	20	5.2%	22	5.7%	1	0.3%	92	24.0%	3	0.8%	16	4.2%	9	2.3%	24	2.3%	
	Advanced			100.0%		55.7%		5.7%		6.3%		0.3%		32.0%		1.0%		4.7%		2.3%		2.3%	**384**
	Placement																						
	Computer																						
	Science A																						
2902	Computer	Female	47	12.6%	19	5.1%	6	1.6%	8	2.1%	0	0.0%	14	3.8%	1	0.3%	2	0.5%	0	0.0%	0	0.0%	
	Programming 2,	Male	326	87.4%	191	51.2%	14	3.8%	15	4.0%	1	0.3%	105	28.2%	3	0.8%	14	3.8%	9	2.4%	24	6.4%	
	Advanced			100.0%		56.3%		5.4%		6.2%		0.3%		31.9%		1.1%		4.3%		2.4%		6.4%	**373**
	Placement																						
	Computer																						
	Science B																						
2965	Computer	Female	13	8.0%	6	3.7%	0	0.0%	2	1.2%	0	0.0%	5	3.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Programming 3,	Male	149	92.0%	86	53.1%	5	3.1%	8	4.9%	0	0.0%	50	30.9%	0	0.0%	6	3.7%	4	2.5%	11	6.8%	
	Advanced			100.0%		56.8%		3.1%		6.2%		0.0%		34.0%		0.0%		3.7%		2.5%		6.8%	**162**
	Placement																						
	Computer																						
	Science A/B																						
2966	Computer	Female	14	8.6%	6	3.7%	0	0.0%	2	1.2%	0	0.0%	6	3.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Programming 3,	Male	149	91.4%	87	53.4%	6	3.7%	8	4.9%	0	0.0%	48	29.4%	0	0.0%	6	3.7%	4	2.5%	10	6.1%	
	Advanced			100.0%		57.1%		3.7%		6.1%		0.0%		33.1%		0.0%		3.7%		2.5%		6.1%	**163**
	Placement																						

Montgomery County Public Schools
2005-2006 Information Technology Course Data

Course Number	Course Title	Gender	Number of Students	%	W	%	AA	%	H	%	IA	%	A	%	ESOL	%	FARMS	%	504 PLAN	%	SEDS	%	Total Enrollment
	Computer Science A/B																						
2991	Web Site Development A	Female	321	31.8%	105	10.4%	106	10.5%	62	6.1%	0	0.0%	48	4.7%	14	1.4%	34	3.4%	7	0.7%	18	1.8%	
		Male	690	68.2%	307	30.4%	159	15.7%	98	9.7%	0	0.0%	126	12.5%	37	3.7%	88	8.7%	22	2.2%	89	8.8%	
				100.0%		40.8%		26.2%		15.8%		0.0%		17.2%		5.0%		12.1%		2.9%		10.6%	**1011**
2992	Web Site Development B	Female	272	30.2%	84	9.3%	82	9.1%	51	5.7%	0	0.0%	55	6.1%	15	1.7%	28	3.1%	5	0.6%	17	1.9%	
		Male	630	69.8%	286	31.7%	154	17.1%	88	9.8%	0	0.0%	102	11.3%	35	3.9%	81	9.0%	19	2.1%	80	8.9%	
				100.0%		41.0%		26.2%		15.4%		0.0%		17.4%		5.5%		12.1%		2.7%		10.8%	**902**
2936	Web Tools and Digital Media Advanced A	Female	19	35.8%	8	15.1%	3	5.7%	4	7.5%	0	0.0%	4	7.5%	0	0.0%	1	1.9%	0	0.0%	1	1.9%	
		Male	34	64.2%	16	30.2%	8	15.1%	5	9.4%	0	0.0%	5	9.4%	2	3.8%	3	5.7%	1	1.9%	4	7.5%	
				100.0%		45.3%		20.8%		17.0%		0.0%		17.0%		3.8%		7.5%		1.9%		9.4%	**53**
2937	Web Tools and Digital Media Advanced B	Female	19	37.3%	6	11.8%	5	9.8%	4	7.8%	0	0.0%	4	7.8%	0	0.0%	1	2.0%	0	0.0%	1	2.0%	
		Male	32	62.7%	16	31.4%	6	11.8%	5	9.8%	0	0.0%	5	9.8%	2	3.9%	3	5.9%	1	2.0%	5	9.8%	
				100.0%		43.1%		21.6%		17.6%		0.0%		17.6%		3.9%		7.8%		2.0%		11.8%	**51**
4232	Database Administration Programming A	Female	5	14.7%	0	0.0%	4	11.8%	1	2.9%	0	0.0%	0	0.0%	0	0.0%	1	2.9%	0	0.0%	0	0.0%	
		Male	29	85.3%	5	14.7%	7	20.6%	9	26.5%	1	2.9%	7	20.6%	1	2.9%	7	20.6%	0	0.0%	5	14.7%	
				100.0%		14.7%		32.4%		29.4%		2.9%		20.6%		2.9%		23.5%		0.0%		14.7%	**34**
4233	Database Administration Programming B	Female	7	26.9%	0	0.0%	4	15.4%	2	7.7%	0	0.0%	1	3.8%	0	0.0%	2	7.7%	0	0.0%	1	3.8%	
		Male	19	73.1%	3	11.5%	3	11.5%	8	30.8%	1	3.8%	4	15.4%	2	7.7%	6	23.1%	0	0.0%	3	11.5%	
				100.0%		11.5%		26.9%		38.5%		3.8%		19.2%		7.7%		30.8%		0.0%		15.4%	**26**
5611	Computer Maintenance Technology A	Female	36	11.5%	10	3.2%	14	4.5%	6	1.9%	0	0.0%	6	1.9%	3	1.0%	5	1.6%	1	0.3%	1	0.3%	
		Male	277	88.5%	102	32.6%	82	26.2%	45	14.4%	0	0.0%	48	15.3%	12	3.8%	41	13.1%	13	4.2%	31	9.9%	
				100.0%		35.8%		30.7%		16.3%		0.0%		17.3%		4.8%		14.7%		4.5%		10.2%	**313**
5616	Computer Maintenance Technology B	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	34	100.0%	16	47.1%	5	14.7%	1	2.9%	0	0.0%	12	35.3%	0	0.0%	5	14.7%	0	0.0%	4	11.8%	
				100.0%		47.1%		14.7%		2.9%		0.0%		35.3%		0.0%		14.7%		0.0%		11.8%	**34**
5613	Computer Maintenance Technology A (DP)	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	5	100.0%	5	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
				100.0%		100.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%	**5**
5614	Computer Maintenance Technology B (DP)	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	5	100.0%	5	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	20.0%	
				100.0%		100.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		20.0%	**5**
4214	Computer	Female	29	25.9%	3	2.7%	15	13.4%	7	6.3%	0	0.0%	4	3.6%	0	0.0%	9	8.0%	0	0.0%	1	0.9%	

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Course Number	Course Title	Gender	Number of Students	%	W	%	AA	%	H	%	IA	%	A	%	ESOL	%	FARMS	%	504 PLAN	%	SEDS	%	Total Enrollment
	Maintenance	Male	83	74.1%	19	17.0%	17	15.2%	33	29.5%	0	0.0%	14	12.5%	4	3.6%	10	8.9%	1	0.9%	12	10.7%	
	Technology A			100.0%		19.6%		28.6%		35.7%		0.0%		16.1%		3.6%		17.0%		0.9%		11.6%	**112**
4215	Computer	Female	24	21.2%	0	0.0%	14	12.4%	6	5.3%	0	0.0%	4	3.5%	0	0.0%	8	7.1%	0	0.0%	1	0.0%	
	Maintenance	Male	89	78.8%	20	17.7%	18	15.9%	32	28.3%	0	0.0%	19	16.8%	6	5.3%	16	14.2%	1	0.9%	13	11.5%	
	Technology B			100.0%		17.7%		28.3%		33.6%		0.0%		20.4%		5.3%		21.2%		0.9%		11.5%	**113**
4216	Computer	Female	4	7.5%	4	7.5%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	1.9%	0	0.0%	
	Maintenance	Male	49	92.5%	30	56.6%	6	11.3%	6	11.3%	0	0.0%	7	13.2%	2	3.8%	12	22.6%	5	9.4%	13	24.5%	
	Technology A			100.0%		64.2%		11.3%		11.3%		0.0%		13.2%		3.8%		22.6%		11.3%		24.5%	**53**
	(DP)																						
4217	Computer	Female	3	6.7%	3	6.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	2.2%	0	0.0%	
	Maintenance	Male	42	93.3%	32	71.1%	4	8.9%	4	8.9%	0	0.0%	2	4.4%	0	0.0%	5	11.1%	5	11.1%	15	33.3%	
	Technology B			100.0%		77.8%		8.9%		8.9%		0.0%		4.4%		0.0%		11.1%		13.3%		33.3%	**45**
	(DP)																						
5615	Computer	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	31	100.0%	14	45.2%	5	16.1%	1	3.2%	0	0.0%	11	35.5%	0	0.0%	4	12.9%	0	0.0%	3	9.7%	
	and LAN			100.0%		45.2%		16.1%		3.2%		0.0%		35.5%		0.0%		12.9%		0.0%		9.7%	**31**
	Management																						
5616	Computer	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	34	100.0%	16	47.1%	5	14.7%	1	2.9%	0	0.0%	12	35.3%	0	0.0%	5	14.7%	0	0.0%	4	11.8%	
	and LAN			100.0%		47.1%		14.7%		2.9%		0.0%		35.3%		0.0%		14.7%		0.0%		11.8%	**34**
	Management																						
4218	Computer	Female	2	4.5%	0	0.0%	2	4.5%	0	0.0%	0	0.0%	0	0.0%	1	2.3%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	42	95.5%	31	70.5%	4	9.1%	4	9.1%	0	0.0%	3	6.8%	0	0.0%	2	4.5%	2	4.5%	4	9.1%	
	and LAN			100.0%		70.5%		13.6%		9.1%		0.0%		6.8%		2.3%		4.5%		4.5%		9.1%	**44**
	Management																						
4219	Computer	Female	2	4.5%	0	0.0%	2	4.5%	0	0.0%	0	0.0%	0	0.0%	1	2.3%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	42	95.5%	31	70.5%	4	9.1%	4	9.1%	0	0.0%	3	6.8%	0	0.0%	2	4.5%	2	4.5%	4	9.1%	
	and LAN			100.0%		70.5%		13.6%		9.1%		0.0%		6.8%		2.3%		4.5%		4.5%		9.1%	**44**
	Management																						
5617	Computer	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	2	100.0%	2	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Technology and			100.0%		100.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%	**2**
	LAN																						
	Management A																						
	(DP)																						
5618	Computer	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Maintenance	Male	1	100.0%	1	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
	Technology and			100.0%		100.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%	**1**

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Course Number	Course Title	Gender	Number of Students	%	W	%	AA	%	H	%	IA	%	A	%	ESOL	%	FARMS	%	504 PLAN	%	SEDS	%	Total Enrollment
	LAN Management B (DP)																						
4220	Computer Maintenance Technology and LAN Management A (DP)	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	24	100.0%	10	41.7%	2	8.3%	3	12.5%	0	0.0%	9	37.5%	0	0.0%	2	8.3%	2	8.3%	4	16.7%	
				100.0%		41.7%		8.3%		12.5%		0.0%		37.5%		0.0%		8.3%		8.3%		16.7%	**24**
4221	Computer Maintenance Technology and LAN Management B (DP)	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	25	100.0%	10	40.0%	2	8.0%	3	12.0%	0	0.0%	10	40.0%	0	0.0%	2	8.0%	2	8.0%	4	16.0%	
				100.0%		40.0%		8.0%		12.0%		0.0%		40.0%		0.0%		8.0%		8.0%		16.0%	**25**
4230	Networking Management, Advanced A	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
4231	Networking Management, Advanced B	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
4055	Software Applications Management A	Female	31	42.5%	8	11.0%	12	16.4%	10	13.7%	0	0.0%	1	1.4%	1	1.4%	8	11.0%	0	0.0%	6	8.2%	
		Male	42	57.5%	8	11.0%	17	11.0%	10	13.7%	0	0.0%	7	9.6%	7	9.6%	11	15.1%	2	2.7%	7	9.6%	
				100.0%		21.9%		27.4%		27.4%		0.0%		11.0%		11.0%		26.0%		2.7%		17.8%	**73**
4056	Software Applications Management B	Female	9	45.0%	3	15.0%	5	25.0%	1	5.0%	0	0.0%	0	0.0%	0	0.0%	2	10.0%	0	0.0%	5	25.0%	
		Male	11	55.0%	1	5.0%	4	20.0%	3	15.0%	0	0.0%	3	15.0%	3	15.0%	3	15.0%	1	5.0%	4	20.0%	
				100.0%		20.0%		45.0%		20.0%		0.0%		15.0%		15.0%		25.0%		5.0%		45.0%	**20**
2903	Software Applications by Design A	Female	2957	53.4%	1254	22.6%	752	13.6%	550	9.9%	8	0.1%	393	7.1%	207	3.7%	368	6.6%	218	3.9%	47	0.8%	
		Male	2581	46.6%	1040	18.8%	643	18.8%	521	9.4%	6	0.1%	371	6.7%	190	3.4%	312	5.6%	58	1.0%	332	6.0%	
				100.0%		41.4%		32.4%		19.3%		0.3%		13.8%		7.2%		12.3%		5.0%		6.8%	**5538**
2904	Software Applications by Design B	Female	2596	53.4%	1125	23.1%	653	13.4%	458	9.4%	5	0.1%	355	7.3%	162	3.3%	306	6.3%	37	0.8%	178	3.7%	
		Male	2267	46.6%	964	19.8%	521	10.7%	445	9.2%	6	0.1%	331	6.8%	171	3.5%	269	5.5%	56	1.2%	286	5.9%	
				100.0%		43.0%		24.1%		18.6%		0.2%		14.1%		6.8%		11.8%		1.9%		9.5%	**4863**
2905	Software Applications by Design, Advanced A	Female	21	31.8%	4	6.1%	5	7.6%	10	15.2%	0	0.0%	2	3.0%	2	3.0%	8	12.1%	0	0.0%	8	12.1%	
		Male	45	68.2%	12	18.2%	9	13.6%	19	28.8%	0	0.0%	5	7.6%	8	12.1%	11	16.7%	2	3.0%	9	13.6%	
				100.0%		24.2%		21.2%		43.9%		0.0%		10.6%		15.2%		28.8%		3.0%		25.8%	**66**
2906	Software Applications by Design, Advanced B	Female	20	35.7%	5	8.9%	6	10.7%	8	14.3%	0	0.0%	1	1.8%	2	3.6%	6	10.7%	0	0.0%	8	14.3%	
		Male	36	64.3%	12	21.4%	9	16.1%	10	17.9%	0	0.0%	5	8.9%	4	7.1%	7	12.5%	2	3.6%	9	16.1%	
				100.0%		30.4%		26.8%		32.1%		0.0%		10.7%		10.7%		23.2%		3.6%		30.4%	**56**

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Course Number	Course Title	Gender	Number of Students	%	W	%	AA	%	H	%	IA	%	A	%	ESOL	%	FARMS	%	504 PLAN	%	SEDS	%	Total Enrollment
2907	Computer Science Internship	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	9	100.0%	7	77.8%	0	0.0%	0	0.0%	0	0.0%	2	22.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
				100.0%		77.8%		0.0%		0.0%		0.0%		22.2%		0.0%		0.0%		0.0%		0.0%	**9**
5706	Internship, Computer Maintenance Technology	Female	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	
		Male	55	100.0%	39	70.9%	0	0.0%	0	0.0%	4	7.3%	12	21.8%	0	0.0%	0	0.0%	2	3.6%	11	20.0%	
				100.0%		70.9%		0.0%		0.0%		7.3%		21.8%		0.0%		0.0%		3.6%		20.0%	**55**
5719	National Academy of Information Technology Internship A	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
5720	National Academy of Information Technology Internship B	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
2938	National Academy of Information Technology Guided Research	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
2939	National Academy of Information Technology Guided Research	Female	0		0		0		0		0		0		0		0		0		0		
		Male	0		0		0		0		0		0		0		0		0		0		
																							0
																						Total:	**17864**

Appendices

Appendix D

Gender and Technology: A Research Review

Gender and Technology: A Research Review

Jo Sanders
Director, Center for Gender Equity

Handbook of Gender in Education

Chris Skelton, Becky Francis, and Lisa Smulyan, editors

Sage Publications, London

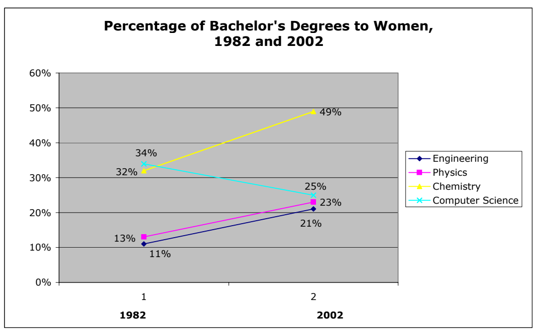
2006

Gender and Technology: A Research Review

Jo Sanders

In 1982, James Johnson, a freelance writer from New Jersey, published an article about inequalities in American society and its schools, optimistically entitled “Can Computers Close the Educational Equity Gap?” (Johnson, 1982). His concern was caused, in large part, by women’s low representation in the sciences. The new field of computer science (CS), though, held promise for women. In 1982 women earned a greater share of Bachelor’s degrees in CS than in engineering, physics, or chemistry. CS, unlike the other fields, didn’t have the centuries-old burden of male history, so perhaps women would be able to enter this new field more easily. (Grant & Snyder, 1986)

As it turned out, Johnson could not have been more wrong. Twenty years later, women have indeed made progress in engineering, physics, and chemistry. Computer science, however, has been another story. (Snyder, Tan & Hoffman, 2004)



While women’s representation in the other sciences rose steadily, their share of CS degrees in those years *dropped* by nearly a third.

Unfortunately, this sorry state of affairs is not limited to the United States. Women are significantly underrepresented in information and communication technologies (ICT) in most countries for which data is available, down to a level of 10 percent or less. (Charles & Bradley, 2005; ENWISE, 2004) In fact, in an analysis of data from 21 countries, researchers noted a “striking cross-national uniformity in the sex-typing of computer science programs.” (Charles & Bradley, 2005) Galpin, in her review of data from 37 countries worldwide, concludes that there is not “a clear pattern that can help to explain why the differences between men and women with respect to computing occur in some countries and cultures, and not in others.” (Galpin, 2002), p. 95) Huyer cites a Nigerian study by Ajayi and Ahbor in which women opposed ICT study because it overexposed young women to a Western lifestyle, thus endangering their chances for marriage. (Huyer, 2003)

Technology therefore earns its place as an anomaly over the past generation or two: an area in which women's professional achievement has actually regressed, as contrasted with virtually all other areas of importance to women. In view of the growing role of technology in the world at the beginning of the 21st century — in education, communications, occupations, and entertainment, and as a tool for solving the world's problems — women's low and decreasing representation is a major worry.

This chapter will explore what we have learned about the intersection of gender, technology, and education: in society; age, stage and pipeline issues; experience, attitudes, and use patterns; in the classroom; and special efforts to remedy the imbalances.

As we embark upon an examination of the research on gender and technology, first a word on methodology. Several researchers have pointed out deficiencies in methods used to collect data on gender differences in computer-related behavior, resulting in inconsistent findings that may be more apparent than real. Statistically significant gender differences may not have any practical value, unstudied variables may influence students' computer-related behavior, and students' self-ratings may be especially problematic due to boys' frequently observed tendency to overestimate, and girls to underestimate, their abilities. (Bannert & Arbinger, 1996; Cooper & Stone, 1996). In reviews of the literature on gender differences in computer-related behavior and attitudes, Kay and others have pointed out methodological and construct inconsistencies that reduce comparability of studies. (Kay, 1992; Morse & Daiute, 1992) It is beyond the scope of this chapter to address these methodological issues in detail but, dear reader, consider yourself warned.

Early work on gender and Information and Communication Technologies (ICT) in education focused on a few issues that are now less relevant.

- Concerns about girls' limited *access* to computers, while well founded at the time, have receded now that schools tend to have sufficient hardware. (Anderson, Welch & Harris, 1983; Campbell & Gulardo, 1984; Sanders, 1985) Access to home computers, however, is still problematic due to competition with male family members (Gunn, 2003), important because students can get as much access to a computer in one weekend at home as in an entire year at school. (Linn, 2005)
- Concerns about girls' low interest in computers because of an association with *mathematics* have receded somewhat but not completely with girls' and women's gains in mathematics since then. (Collis, 1985b; Dambrot, Watkins-Malek et al., 1985; Gressard & Loyd, 1987; Munger & Loyd, 1989)
- Finally, concerns about college women's *physical safety* going to and from the computer lab at night have diminished as computers have become more omnipresent. (Palmer, 1989; Pearl, Pollack, et al., 1990)

In 1984 Sanders published a list of 29 "speculations" about the causes of the computer gender gap and called for research in each area. Much of the work since then has focused on issues she identified. (Sanders, 1984)

As a framework for the analysis that follows, Littleton and Hoyles posit three developmental stages with respect to gender and technology.

- Stage 1: noticing the gender imbalance at home, in school, and in attitudes.
- Stage 2: changing female participation in ICTactivities through role models and collaborative groupings.
- Stage 3: challenging the dominant paradigm of ICT as culturally and historically male. (Littleton & Hoyles, 2002)

As will be seen, the majority of the research to date falls solidly into their Stage 1, with some in Stage 2. There is very little in Stage 3, although there is a good amount of published work that acknowledges the male paradigm. However, because this analysis is limited to research on gender *and technology*, it is important to remember that relevant research may exist in the related areas of science and mathematics.

1. Societal Influences

Because gender bias pervades societies throughout the world, we can expect to find gender bias influencing girls' choices in many ways. As Vasilios Makrakis put it, "a gender-biased society teaches girls to have gender-stereotyped interests." (Makrakis, 1992, p. 285)

Parents. Parents are one source of gender stereotypes with respect to computing. In Romania and Scotland, parents had more stereotyped computer attitudes than their children. (Durndell, Cameron, et al., 1997) In the United States, parents, especially white and high-SES parents, were found to give less computer-related support to girls than to boys (Kekelis, Ancheta, et al., 2005). Shashaani found that parents' computer stereotypes in favor of males encouraged their sons' computer involvement and discouraged their daughters' (Shashaani, 1994), and that girls who perceived their parents as believing computers were more appropriate for males were in fact less interested in computers (Shashaani, 1997). The results of another study of Iranian students echoed Shashaani's 1997 findings for American children. (Shashaani & Khalili, 2001). Finally, while not specifically about computers but relevant for our purposes, an intriguing study of family behavior in science museums found that both parents but especially fathers explained the content of interactive science exhibits three times more to sons than to daughters, even to children as young as one, while parents were twice as likely to explain the content of interactive music exhibits to daughters than to sons. (Crowley, 2000)

Media. Magazines have been reviewed for gender stereotyping and found wanting by several researchers. (Knupfer, Kramer & Pryor, 1997; Ware & Stuck, 1985). In analyzing a computer magazine written for educators, Sanders found that men were about 75 percent of people portrayed and mentioned. (Sanders, 1998) Knupfer examined computer advertisements, the Internet, television and movies and found rampant gender stereotypes about people in technical roles. (Knupfer, 1998; Knupfer, Rust & Mahoney, 1997) Hoyles wrote a good review of the literature on the stereotyped public image of computers. (Hoyles, 1988).

Race and Ethnicity. Many reports exist that students of color are afforded lesser computer opportunities than white students. (Eastman, 1995; Goode, 2005; Maxwell, 2000). Computer camps have been observed to enroll white children out of proportion to their numbers in the population. (Hess & Miura, 1985) I found two papers that specifically addressed the situation of females of color with respect to computing, pointing out that such students are subject to the double discriminatory burden of femaleness and minority status. (Edwards, 1992; Women and Minorities in Information Technology Forum, 1999) Morrell found that a day-long Saturday program for middle school girls had a stronger effect on girls of color than white girls. (Morrell, Cotten, et al., 2004). Another extracurricular program, Techbridge in California, discovered that girls were self-segregating by race and that racial tensions developed in the group. When staff tried intervention activities, it was noted that girls with lesser technical skills and lower self-confidence were at particular risk of dropping out from attempts to force them to cross racial lines. The interventions were only partially successful. (Kekelis, Ancheta, et al., 2004)

Socio-Economic Status. Often incorrectly confounded with racial/ethnic factors, studies in the United States, Australia, Iran, and the UK were unanimous in correlating high parental SES, particularly higher parental educational achievement, with greater computer encouragement of girls. (Attewell & Battle, 1999; Chambers & Clarke, 1987; Kirkman, 1993; Shashaani, 1994; Shashaani & Khalili, 2001). Children attending lower SES schools had poorer computer resources and were less likely to have computers at home. (Hickling-Hudson, 1992; Opie, 1998)

Male culture of ICT. There is a wealth of research on the male-dominated culture of computing. Among the commentators who have pointed out the negative effects of this culture on women are the Information Technology Association of America, the American Association of University Women, and the New York Times. (American Association of University Women Educational Foundation Commission on Technology, Gender and Teacher Education, 2000; Information Technology Association of America, 2003; Markoff, 1989) Thoughtful analyses of the hallmarks of the male computing culture — invisibility, exclusion, condescension, hostility, an emphasis on speed and competitiveness, and other dynamics — have been published every decade since the 80s. (MIT Computer Science Female Graduate Students and Research Staff, 1983; Seymour & Hewitt, 1997; Gurer & Camp, 2002; Margolis & Fisher, 2002) Women students speak of "the harassment of continually bumping into male egos." (Durndell, Siann & Glissov, 1990, p. 159) We are reminded, however, that "even male, experienced engineering and science students encountered computing as an alien culture," making us wonder who then is well served. (Sproull, Zubrow & Kiesler, 1986, p. 257) Elkjaer, writing of ICT in Denmark, points out that masculinity, not femininity, is the problem when boys retreat into the computer to avoid human interactions and when they consider themselves the hosts in that environment, with girls as guests. (Elkjaer, 1992)

Several researchers have indicated that the violent language of technology may be invisible to males but can be a problem for females. Consider hard disc, hard drive, reboot, cold boot, hits, permanent fatal error, and so forth. Recreational or even educational software for children often includes title words such as “attack” or “war.” (Buckley, 1988; Cole, Conlon et al., 1994; Gurer & Camp, 1998; Linn, 1999; Spertus, 1991)

Students at the high school and even younger levels in the United States, Canada, and New Zealand have negative notions of the computer culture and computer enthusiasts as geeky, nerdy, social isolates who are adolescent, competitive, and exclusively focused on programming. (Johnson, Johnson & Stanne, 1985; Klawe & Leveson, 2001; Pearl, Pollack, et al., 1990; Selby, 1997). These factors have also been widely noted at the postsecondary level. (Dryburgh, 2000; Durndell, 1990; McCormick & McCormick, 1991; MIT Department of Electrical Engineering & Computer Science, 1995)

In short, one study concludes that “it is not necessarily computers and technology *per se* that females avoid, but rather the competitive, male environment that surrounds the field.” (Canada & Brusca, 1991, p. 47) The male-intensive computer culture can change, however, when the proportion of women increases. This factor is discussed in Section 4, In the Classroom, below.

2. Age, Stage, and Pipeline Issues

Preschool. Gender issues in computing have been studied for children as young as three, and findings are inconsistent. Most found gender differences in preschool children’ attitudes and behavior. Boys but not girls showed a preference for action-oriented software. (Calvert, Watson, et al., 1989) While preschool-age boys spent longer at the computer than girls, girls’ computer use increased with time. (Bernhard, 1992; Currell, 1990) In New Zealand, three- and four-year old boys considered computers to be for boys while girls thought they were for both boys and girls. (Fletcher-Flinn & Suddendorf, 1996) One study found that boys viewed the computer as masculine but girls saw it as feminine (Williams & Ogletree, 1992), while another early study found no gender stereotyping among preschoolers at all. (Beeson & Spillers, 1985)

Gender Differences by Age. Most but not all studies have found that gender differences in attitudes and behavior are relatively small at younger ages but increase as students become older. (Hattie & Fitzgerald, 1987; Kirkpatrick & Cuban, 1998; McCormick & McCormick, 1991; Reece, 1986). Twelfth-grade girls in Canada and in China showed a decline in computer attitudes when compared to eighth-grade girls. (Collis & Williams, 1987) A study of college students showed no gender difference by age of student, but this may have been due to the short time span involved. (Koohang, 1986) In contrast, a study by the U.S. Department of Education found that use patterns did not change from elementary to high school. (Freeman, 2004) Another study found gender differences in age which were due more to computer experience than to age. (Dyck & Smither, 1994) On the whole, however, effect sizes in studies on age were larger for older students than for younger ones. Whitley, in a review of 82 studies, concluded: “[G]ender differences in attitudes toward computers result from socialization processes: the longer that children are in school, the greater the gender difference becomes.” (Whitley, 1997) He noted, however, that such differences were smaller for college-level students and speculated that perhaps young women with more positive computer attitudes were more likely to go to college.

Pipeline Issues. The term "pipeline" refers to the trajectory from taking computer courses in high school on through college or graduate school and into ICT careers. Certainly the status quo, in the United States at least, gives no reason for complacency: a 2004 survey of college freshman revealed that 88 percent of students who intended to major in computer science were male. (College Entrance Examination Board, 2004)

The researcher most associated with identifying the factors in the loss of females in computing from high school through careers is Tracy Camp. (Camp, 1997a, 1997b, 2000; Gurer & Camp, 1998, 2002) One cause frequently mentioned for the loss of women along the pipeline is lack of accurate information about ICT careers (Chan, Stafford, et al., 2000; Goode, Estrella, & Margolis, 2005; Jepson & Perl, 2002; Kekelis, Ancheta, et al., 2005). Closely related is the prevalence in the many students' minds of negative stereotypes about computer workers. (Clarke & Teague, 1996; Culley, 1998; Klawe & Leveson, 2001) Sanders and Lubetkin remind us to include technician-level occupations in pipeline considerations, since most women are not college educated. (Sanders & Lubetkin, 1991)

This entire chapter is, in a sense, an explanation for the "leaky pipeline" for women in technology. However, several writers have offered additional reasons: family balance problems (Pearl, Pollack, et al., 1990), the use of freshman courses to weed out students (Bohonak, 1995), and less financial support than men have (Leveson, 1990). A particularly interesting theory comes from the analysis of data from 21 countries: women's ICT representation tends to be relatively high in countries that score low as liberal egalitarian societies. They speculate that in countries where women have a freer choice of careers, gender stereotypes lead them to make stereotyped career choices, and that "[R]estrictive government practices that minimize choice and prioritize merit may actually result in more gender-neutral distribution across fields of study." They conclude that sex segregation in computing is linked to "deeply rooted cultural assumptions about gender difference." (Charles & Bradley, 2005)

Two projects have focused on helping adult women change careers into IT. A bridge program was formed for adults with bachelor's degrees in other areas. (Davies, Klawe, et al., 2000) In a project conducted in Massachusetts, it was found that IT workers were doing the same work regardless of the educational path they took to get there, and that women were more likely to have gotten there because they learned programming from being shown rather than by reading programming books. (Campbell, 2004). A fascinating survey of women's career paths to IT positions found that women followed multiple academic routes. In fact, only 12 percent of them had earned undergraduate and graduate degrees in computer science, and a full two-thirds had not majored in computer science as undergraduates. (Turner, Bernt & Pecora, 2002)

3. Experience, Attitude and Use Patterns

Experience. An overwhelming majority of studies have found that boys have greater computer experience than girls, and in many countries: the United States, Australia, Norway, Canada, England, Scotland, Israel, Iran, and in multi-country studies. Boys have an edge in home computer use, school computer use, computer course-taking, games, and in free-time exploratory use. Of these, games and free-time exploratory use are most frequently cited as the primary causes of boys' greater computer experience. Computer course-taking in high school in the U.S. was roughly equal until 1994; however, the latest data (for 2001) show that it is more unequal now, favoring boys, than at any time since such data were collected in 1982. (Snyder, Tan & Hoffman, 2004, Table 137)

A few studies, however, have not found greater male computer experience. In 1992 Liu and colleagues found that girls had more prior computer experience than boys. (Liu, Min & Phillips, 1992) Other studies found negligible or no differences in experience. (Freeman, 2004; Whitley, 1997) Robin Kay, in a review of 38 studies, found that males had more experience in 30 studies, females in four, and no difference in four. (Kay, 1992) In the United States, student computer use (as opposed to course-taking) is now for the most part equal (Snyder, Tan & Hoffman, 2004), with the following exceptions: use of the Internet is equal until college, at which point females use it more than males (Table 426); computer use for school purposes is equal until college, at which point males use it more (Table 429). A recent study in Scotland found that college women were less likely to own a computer than their male counterparts. (Gunn, 2003) This may be due to unequal financial resources.

Beyond overall experience patterns, several studies have had particularly interesting, although inconsistent, results. When first-year college students were randomly assigned to a writing course with required or optional (optional meaning computers and instruction were readily available) computer use, females' computer use levels by the end of the course were higher in the computer-required condition than for females in the optional condition or for males in either condition, suggesting that requiring the use of computers may be beneficial. (Arch & Cummins, 1989) A large number of children in grades 4 to 10 were surveyed annually for three years; the more experienced the students became with computers, the less confidence they had in their computer skills, and this was particularly true for girls. The authors conclude that experience alone will not close the computer gender gap. (Krendl, Broihier & Fleetwood, 1989) In most studies dealing with experience and attitudes, though, greater experience tended to result in improved attitudes. When children ages 10 to 15 were surveyed about their computer experience, girls indicated about the same number of hours per week as boys when they completed the questionnaire in same-sex groups but significantly less time when in mixed-sex groups. (Cooper & Stone, 1996)

In a well known effort to increase women's CS enrollment at Carnegie Mellon University, it was observed that foreign women tended to have less computer experience than American women — sometimes none at all — but nevertheless persisted because of economic and pragmatic realities. (Margolis & Fisher, 2002; Margolis, Fisher & Miller, n.d.-b) Gurer and Camp have pointed out that when instructors in prerequisite courses for ICT majors in college discover that women have not had extensive computer experience, they erroneously infer the women's lack of ability or interest which presumably leads to differential treatment in class. (Gurer & Camp, 2002)

Attitudes. There has been more research on attitudes about computers, by far, than about any other topic, and perhaps more confusion as well. Published studies number literally in the hundreds, using dozens of home-grown as well as validated instruments. Definitions are not reliably consistent; even the term "computer" means different things to preschoolers than graduate students. Volman and Eck have pointed out that gender differences in computer attitudes are both a cause and a consequence of gender differences in ICT participation and performance. (Volman & Eck, 2001) Within these constraints, I will summarize the highlights here.

Liking and Interest. With some exceptions, many studies and in many countries find that boys have more positive feelings about the computer than girls — boys tend to like computers more and are more interested in them. Again with some exceptions, many studies find that level of computer experience correlates with liking and interest. Typically, studies find that computer liking and interest decrease with age for both girls and boys but more strongly for girls. (Gurer & Camp, 2002; Lage, 1991; Shashaani, 1993; Whitley, 1997) Krendl found that while girls' attitudes decrease with age, their sense of computers' value and usefulness increases. (Krendl, Broihier & Fleetwood, 1989) In a 1999 meta-analysis of 106 studies, Liao found that males had slightly more positive computer attitudes (Liao, 1999), while another study established that girls' and boys' computer attitudes were equal when the factors of experience and gender stereotyping were removed (Colley, Gale & Harris, 1994). Computer attitudes were seen to correlate with math attitudes (Shashaani, 1995), and were affected by socio-economic status in a study linking lower-SES girls with high computer liking. (Miura, 1987) Margolis and her colleagues have explored computer interest in several studies, finally concluding that in the "nexus of confidence and interest" (Margolis, Fisher & Miller, 2000, p. 7), a female's loss of confidence in her computer abilities precedes a drop in her interest in computers. (Margolis & Fisher, 2000) In many studies boys invariably saw computers and computer skills as male-associated; females differed, seeing them as male or neutral or, in a few cases, female.

Comfort and Confidence. By and large, studies find that females' comfort level with computers increases (and anxiety decreases) with experience. I found several studies that examined the relationship of computer confidence with masculinity or femininity as measured by the Bem Sex Role Inventory, and all five agreed that positive computer attitudes correlated with high masculinity for both males and females, not with maleness *per se*. (Brosnan, 1998a, 1998b; Charlton, 1999; Colley, Gale, & Harris, 1994; Ogletree & Williams, 1990) Another determined that girls scoring high-feminine were drawn to Web sites by their appearance, while high-masculine girls were drawn by their content. (Agosto, 2004)

Some studies found that males' and females' confidence in their computer ability was equal (DeRemer, 1990; Dyck & Smither, 1994; Houle, 1996; Jennings &

Onwuegbuzie, 2001), but most found females' confidence level significantly lower than that of males even when females were more successful than the males in the class. (Gurer & Camp, 1998; Selby, 1997; Shashaani, 1997) Girls with lower confidence are likelier to drop out of computer programs (Kekelis, Ancheta, et al., 2004). Parental encouragement correlates with confidence for both girls and boys, but boys receive more of it. (Shashaani, 1994; Shashaani & Khalili, 2001) Girls had lower confidence in their computer skills in studies conducted in Hong Kong (Lee, 2003), Australia (Lee, 1997; Ring, 1991), New Zealand (Selby, 1997), and in a 20-nation study (Reinen & Plomp, 1993). In the United States in a huge annual survey of incoming college freshmen, the gender gap in computer confidence was wider than it had ever been in the 35 years of the survey, with males twice as likely as females to view their computer skills as above average. (Sax, Astin, et al., 2001) A recent approach to boosting females' computer confidence, however, is "pair programming," discussed in Section 4, In the Classroom.

Anxiety. There is also a healthy literature on computer anxiety, although it seems to have wound down a bit. Most studies have found computer anxiety higher in females than in males, at all ages and in many countries. One study found that females who dropped out of computer courses had higher computer anxiety than those who stayed, but that males who dropped out had *lower* anxiety than those who stayed. (Nelson, Weise & Cooper,1991) Another, following students for three years, found girls more anxious than boys in grade 7, equal in grade 9 and lower in grade ll. (King, Bond & Blandford, 2002) Examining survey results of incoming college freshmen from 1992 to 1998, it was found that over the years the males became less computer-anxious while the females became more so. (Todman, 2000) Whitley determined that prior experience did not mediate gender differences in anxiety, but that anxiety mediated gender differences in computer behavior. (Whitley, 1996)

Self-Efficacy. The final computer attitude to be examined here is the self-efficacy, competence, skill, and aptitude cluster. The overall conclusion from the research is that females consistently under-estimate their technology skills regardless of what their skills really are. Betty Collis memorably referred to girls' tendency to deprecate their own skills but assert confidence in females' skills in general as the "I can't, but we can" paradox. (Collis, 1985a) This theme was heard again in Japan (Makrakis, 1993) and in the U.S. nearly 20 years later. (Shashaani, 1993) Several authors consider that males who denigrate females' computer skills are a source of females' low self-confidence. (MIT Computer Science Female Graduate Students and Research Staff, 1983; Temple & Lips, 1989; Wasburn & Miller, 2005) Any discussion of females' computer competence must be filtered through Henwood's astute perception about the minority of women in university-level computing programs who see themselves, and are seen by men, as exceptional "and therefore, by implication, different from the majority of women, who are thereby rendered incompetent and outsiders in technological culture. … [T]he task of changing the outcomes of women's education in computer technologies is more complicated than simply teaching them how to use computers. … It is also necessary to change how the women (and the men around them) understand and talk about the presence and competence of women." (Henwood, 1999, p. 24 and 25)

Nearly a decade of surveys in the UK of university students from the mid-80s to the mid-90's revealed that women continued to believe they had deficient computer skills, despite an increase in everyone's computer skills. (Durndell & Thomson, 1997) In South Africa, female university ICT students predicted they would receive lower grades for the course than males; in reality they received quite similar grades. (Galpin, Sanders, et al., 2003) A review of 32 studies on gender and computer aptitude, skills and abilities found that males performed better than females in 14, equally in 13, and less well in five. (Kay, 1992) In a university where all students have their own laptops, students used them similarly but females still rated their skill levels lower than males. (McCoy & Heafner, 2004) Young found that middle-school boys had more confidence in their computer skills despite their teachers' deliberate encouragement of girls, despite the girls' disbelief that computers were for boys, and despite the boys' feeling that teachers did not take their interest in computer careers seriously. (Young, 1999)

To end this discussion of attitudes, Brosnan in a 1994 research review of "computerphobia" concluded that there is no agreement among researchers about the relative strength of attitude, experience, and related factors to account for females' and males' computer behavior. (Brosnan, 1994) Over ten years later, I would concur but would go further: there isn't even agreement about the meaning of the terms and concepts involved.

<u>Computer Use Patterns</u>. The first programmers were eighty women (their job title was "computers") who calculated ballistics trajectories on the ENIAC computer during World War II at the University of Pennsylvania. (Women in Technology International, 1997) Since then, however, *programming* has become a male enclave with high school, college, and graduate programming enrollments primarily male. As early as 1983 this was noted with concern. (Anderson, Welch & Harris, 1983; Bakon, Nielsen & McKenzie, 1983) One barrier to female programming enrollment is the negative stereotype of the geeky computer nerd, discussed at the beginning of this chapter. Another is that many females erroneously believe that computer science is nothing but programming, an unpleasant prospect to them. (Fisher, 1997; Margolis & Fisher, 2002) Female under-representation in programming is still a cause for concern because there is a correlation between taking programming in high school and persistence in CS in college. (Nelson, Weise & Cooper, 1991) Programming experience was found to be four times more predictive of CS success in college for women than it is for men (Taylor & Mounfield, 1994), and that knowledge of applications alone without programming had no predictive value. Despite females' programming under-enrollment, two empirical studies have found female superiority in programming tasks. (Ayersman & Reed, 1995; Mandinach & Linn, 1987) In one study, all the girls taking a high school programming course had male relatives in technical jobs. (Goode, Estrella & Margolis, 2005)

Advanced Placement Courses. The Advanced Placement (AP) program in the United States gives college credit to students who pass advanced courses taken in high school. Female participation in the computer science AP exams on programming languages (e.g., Pascal, C++, and now Java) has decreased substantially since their start in 1984. (Stumpf & Stanley, 1997) Recently it was shown that girls who achieved highly in mathematics were less likely than boys with similar scores to enroll in AP computer science courses and received lower scores on the AP exams. (Sanders & Nelson, 2004)

Games. As the focus of this book is education I will not cover computer games in any detail other than to say that dozens of studies have established boys' overwhelming primacy in this area. (Cassell & Jenkins, 1998; Goodfellow, 1996) Boys tend to play games starting at young ages and for long periods of time, and persist in game-playing as they get older; girls tend not to follow these patterns. Many observers have speculated that this early male advantage at games produces confidence with the medium and eventually translates into male primacy in ICT as adults, but there has been no research support for this as yet.

Telecommunications. The Internet presents quite a different picture. In the United States, use of the Internet in 2001 (most recent data available) was roughly equal by students of all ages in school, with a slight male advantage at younger ages and a slight female advantage beginning in high school. (Snyder, Tan & Hoffman, 2004, Table 426) At home, Internet usage remained roughly equal until graduate school, when females had an advantage. (Snyder, Tan & Hoffman, 2004, Table 428). One disturbing note is that 82 percent of applicants to higher education institutions who applied online were male, while the proportion by sex was more equal with paper applications. (Hirt, Murray & McBee, 2000)

Distance Learning. Evidence here is contradictory, with some showing positive and some negative results for women in distance learning. Two studies indicated that females do better in electronic learning environments, or at least prefer them, than in face-to-face classrooms (Hsi & Hoadley, 1997; Leong & Hawamdeh, 1999) One study found that online academic discussions equalized female and male contributions. (Linn, 2005) In New Zealand, women performed better online than in a classroom environment in a Web design course. (Gunn, 2003) More women posted more frequently than males in an online chemistry course, significant in part because frequency of posting correlated positively with course performance, especially for women. (Kimbrough, 1999) Others found nonexistent or tiny gender differences in online behavior. (Atan, Sulaiman, et al., 2002; Atan, Azli, et al., 2002; Davidson-Shivers, Morris & Sriwongkol, 2003; Ory, Bullock & Burnaska, 1997)

Some evidence shows negative results for distance learning. Roy and colleagues found that females preferred classroom learning to the electronic version. (Roy, Taylor & Chi, 2003) Males' unpleasant online behavior discouraged female participation. (Herring, 1992, 1999, 2000). Researchers in the U.S., the UK, and Australia found gender-role stereotypes, sometimes including outright hostility, reproduced in an online environment. (Barrett & Lally, 1999; Cook, Leathwood & Oriogon, 2001; Myers, Bennett & Lysaght, 2004 respectively) In the Australian study the instructor declined to deal with male online hostility despite repeated requests from female students. Family considerations entered in when women were did their online coursework later at night than men and when women reported they had less access to computers than men because of the need to share it with others in the family; grades, however, were equal. (Gunn,

2003) There is a recognition that online instructional designers need to understand the pedagogical needs of many women. (Campbell, 2000; Knupfer, 1997)

Software. The very existence of software "for girls" confirms that software is indeed for boys. Early on it was clearly seen that software was designed by males for males. (Kiesler, Sproull & Eccles, 1983) Software developed for girls has been based on common gender stereotypes: "shopping, makeup, fashion, dating," (Rubin, Murray, et al., 1997, p. 1) and described as "saccharine, boring, and stereotyped" (Manes, 1997). Software titles for girls "perpetuate sexism and serve only to enrich the companies that produce them." (Linn, 1999, p. 16) Sexism in software occurs in characters, content, reward systems, and structure. (Bhargava, Kirova-Petrovna & McNair, 2002) In an empirical study, Cooper and Hall showed that middle-school girls who used violent math software had more anxiety and lower math performance than girls who used verbally based math software, and more than boys using either type. (Cooper & Hall, 1986)

Math software has repeatedly been shown to feature male characters, but this line of research peaked about ten years ago. (Chappell, 1996; Hodes, 1995) According to Joiner, however, the sex of the main character made no difference to children (Joiner, Messer, et al.,1996), and Littleton and colleagues found the intrinsic interest of the software more influential with children than the sex of the main character. (Littleton, Light, et al., 1998) Teacher intervention has been shown to be effective in correcting children's frequent assumption that ambiguous software characters are male. (Bradshaw, Clegg & Trayhurn,1995)

Teachers, females and males alike, play a helping role in stereotyped software. When asked to evaluate educational software, teachers identified gender bias only when specifically asked to look for it and even then only sporadically. (Rosenthal & Demetrulius, 1988) When teachers from grade 1 through college were asked to design software for girls, boys or students, they designed tool software for girls and game software featuring violence and competitiveness for boys and students. (Huff & Cooper, 1987) Fifteen years later the repeated experiment obtained exactly the same result: "[w]e conclude that it is not the computer, or even the software, that is at the root of the sex bias in software, but the expectations and stereotypes of the designers of the software." (Huff, 2002, p. 519)

There has been little recent research on gender and software. It is not clear if this is because current educational software makes a gender analysis irrelevant or if the topic has merely dropped out of fashion.

4. In the Classroom

<u>Peers</u>. Several empirical studies revealed substantial gender stereotyping among students, which influences their peers. When British college students rated written descriptions of "Stephen's" and "Susan's" identical programming experience for their skill level, both sexes rated "Stephen's" programming ability higher than "Susan's." (Colley, Hill, et al., 1995) Especially interesting are several experiments with university

students by Clifford Nass. When computers "spoke" about male- or female-stereotypical topics in synthetic low- (male) or high-pitched (female) voices, college students of both sexes rated the "female" computer more knowledgeable about feminine topics and the male computer more knowledgeable about male topics. Students of both sexes found evaluation from the "male" computer more credible. Nevertheless, students denied harboring stereotypes or being influenced by the gender of the computer voices. (Nass & Brave, 2005; Nass, Moon, & Green, 1997) Consistently, girls and boys believed males to be better at computing than females; just as consistently, boys were more likely to hold stronger stereotypes in this regard than girls. (Durndell, Glissov & Siann, 1995; Eastman & Krendl, 1987; Levin & Gordon, 1989; Shashaani, 1993) However, women who took technological career paths credited male peers and siblings for encouraging them. (Smith, 2000)

Public/Private Context and Stereotype Threat. The social context of computing makes a difference. Several studies have found that both sexes performed a computer task worse in public than in private when they expected it to be difficult. (Cooper, Hall; & Huff, 1990; Robinson-Staveley & Cooper, 1990; Tsai, 2002) Another found that only girls performed worse in public. (Cooper & Hall, 1986). When girls used software designed by teachers for boys, they experienced more "situational stress" in a public setting than in a private one. (Huff, 2002) A study of college students found that the presence of another person resulted in lower performance on a computer task among women with little previous computer experience than when alone, while for men another person's presence had the opposite effect. Males and females with extensive computer experience were unaffected. (Robinson-Staveley & Cooper, 1990)

The sex of the observer apparently matters. Girls performed a computer task better when alone or in the presence of female observers than male observers. (Corston & Colman, 1996) Ten- to15-year-old girls in the presence of boys related to the computer in more gender-stereotyped ways than in the presence of girls: "This suggests that gender differences in computer use may be a function of the classroom context." (Cooper & Stone, 1996)

This research clearly raises the issue of stereotype threat, the anxiety felt in evaluative contexts (e.g., tests, public speaking, etc.) by people who identify with groups about which a negative stereotype exists because they are concerned they might confirm the stereotype about their group or themselves. The anxiety itself seems to decrease performance, which appears to confirm the stereotype. (Aronson, 2002, 2004; Steele, 1997) There have been several studies confirming the stereotype threat effect for females in math, in which females performed worse when their female identity was emphasized (Inzlicht & Ben-Zeev, 2000; Shih, Pittinsky & Ambady, 1999; Spencer, Steele & Quinn, 1999) and even one on knowledge of politics and civics (McGlone & Aronson, in press), but none as yet in technology. I would expect the outcome to be similar.

Pedagogy. Hundreds of papers and articles deal with pedagogical issues in gender and technology, but most of them simply describe programs without evaluating (or for some even presenting) outcomes, or they repeat commonly accepted notions rather than contributing new knowledge. The assertion of a technique, no matter how frequent, or even a finding that girls like it still leaves open the question of whether it is in fact better for their learning or persistence in technology.

Collaboration. Very few studies escaped the assertion trap here. When students could freely choose, girls chose to work collaboratively on the computer while boys chose to work individually. (Ching, Kafait & Marshall, 2002) Girls describe their ideal computer use as one that permits collaboration and sharing, while boys fantasized about computers giving them power and speed. (Brunner, 1992) Sixth- to 12th-grade girls preferred software that required them to collaborate rather than compete. (Miller, Chaika & Groppe, 1996)

Single- vs. Mixed-Sex Environments. Much of the research on this topic is problematic. Girls (or girls' parents) who voluntarily choose single-sex schools or classes may well have other characteristics, such as academic orientation, that might account more strongly for any differences found. Randomization would control for this but no studies have as yet done so. Many do not specify the basis for condition assignment, thus limiting their value. In addition, many studies that contrast single-sex with coed settings have different and non-comparable teachers, curriculum, or other circumstances, further limiting their value. (Campbell & Sanders, 2002) In the United States, for example, most if not all of the single-sex projects that are funded have optional participation. In a study of over 400 projects on females in science, technology, engineering, and mathematics, 57 percent were for females only and did not have coed control groups. (American Association of University Women Educational Foundation Commission on Technology, Gender, and Teacher Education, 2004) One researcher warns that some single-sex programs risk appealing to girls on the basis of gender stereotypes, much as we have seen software do. (Volman, 1990)

Some ICT-oriented research found positive results. In England, female university students who took a computer course as non-majors had more computer confidence if they had attended a single-sex school than a coed school. (Carter & Jenkins, 2001) Also in England, instructions were given to children in single-sex and mixed-sex groups to collaborate on a computer task. Mixed-sex groups refused or were unable to collaborate; female groups did so regardless of the instructions; and male groups collaborated more than previously. (Underwood & Jindal, 1994) Middle-school age girls in South African single-sex schools had higher computer self-efficacy measures than girls from coed schools. (Galpin, Sanders, et al., 2003) In Northern Ireland, girls at coed schools were likelier to agree that boys were better at computers. (Gardner, McEwen & Curry, 1986) First grade girls in the U.S. who composed stories on the computer in mixed-sex groups were laughed at and criticized by the boys, while all-female groups worked well and smoothly. (Nicholson, Gelpi & Young, 1998)

Others have come up with different results. Two different studies of single-sex and co-ed schools in Australia found that girls had more computer experience and more positive computer in the single-sex schools; however when experience was held constant there was no effect for educational setting on attitudes. (Craig, Fisher, et al., 1998; Jones

& Clarke, 1995) Unexpectedly, Hughes et al. found that all-female groups performed computer tasks worse than mixed-sex groups because of females' lower confidence levels, and that girls who had been part of female pairs subsequently did worse than girls who had been part of mixed-sex pairs. (Hughes, Brackenridge, et al., 1988) One study,however, found that males and females performed equally well in single-sex pairs and better than in coed pairs. (Underwood, McCaffrey & Underwood, 1990) Oberman found that high school girls preferred to work individually, not in groups of any composition. (Oberman, 2000)

Some researchers have found overwhelming resistance to single-sex approaches. A program in Australia was disbanded due to hostility from staff and students of both sexes. (Clayton & Lynch, 2002) A Canadian program in which female teachers and students were selected for the first computer training in the school so that they could teach others met with active resistance from faculty and parents. (Jenson, de Castell & Bryson, 2003) In a paper on computer equity efforts in five European countries, it was observed that some single-sex courses were resisted by females as "self-consciousness training." (Sorenson et al., 2003, p. 16) Cohoon has observed that women's resistance to single-sex activities is related to their wish to evade stereotype threat situations. (Cohoon, 2005)

Perhaps the most interesting recent research on the single-sex approach is pair programming. Werner and her colleagues have found that both female and male pairs of university students, but especially women, were more likely to complete their computer course and major in computer science than mixed-sex pairs or students working solo. There is no information as yet on the pair selection procedures but this may be a promising avenue of research. (Werner, Hanks, et al., 2005; Werner, McDowell & Hanks, 2004)

In short, the hotly debated topic of single-sex education shows no signs of being clarified any time soon, the identical conclusion drawn by Sutton back in 1991. (Sutton, 1991)

Critical Mass. A closely related issue is critical mass. The classic work is Rosabeth Moss Kanter's analysis of the social dynamics of majorities and minorities. (Kanter, 1977; Kanter & Stein, 1993) Sanders discovered that it is not the presence of boys at the computers that discourages girls' participation, but rather the absence of the girls' girlfriends. (Sanders, 1985) Probably the best recent study is by Cohoon, who found that a critical mass of other women correlated more strongly than any other factor with women's retention in computer science majors in Virginia (USA) universities. (Cohoon, 2001) One of the factors credited for raising the female presence in Carnegie Mellon University's (CMU) School of Computer Science was the critical mass provided by increasing numbers of women. (Blum, 2001a) According to several theorists, when computer enrollment becomes more equalized by sex, the culture changes in ways that are positive for both men and women. (Blum & Frieze, 2005; Etzkowitz, Kemelgor, et al., 1992) The computer science department at the Massachusetts Institute of Technology lowered test score admission requirements and admitted more women, who then raised academic standards overall once their numbers increased. (Linn, 2005) In a related area, however, Sanders found that when teachers worked with colleagues from their own schools (in a critical mass effect) on gender equity projects for girls they were not more successful than teachers working alone. (Sanders, 1996)

Support groups are an attempt to create a critical mass. I found nothing on the effectiveness of support groups for women's learning or persistence, although they are often mentioned as desirable. One source described an unsuccessful support group in college women in CS that never got off the ground, perhaps because of the lack of a critical mass of female students. (Margolis & Fisher, 2002) Several papers, however, described successful support group approaches in detail. (Blum, 2001a, 2001b; Frieze & Blum, 2002)

Mentors and Role Models. Many studies (and students) confuse these two related concepts. A mentor is a trusted and known guide and adviser; a role model is a person looked upon as an example to follow, who may not be personally known. There are a few good studies on faculty as mentors. Cohoon determined that the time that computer science faculty of either sex spent mentoring female students correlated with the students' retention in CS. (Cohoon, 2001) She also found that computer science faculty spent less time mentoring female students than biology faculty did; there is of course a higher percentage of female enrollment in biology. (Cohoon, 2002) In a study of college freshmen at SUNY-Binghamton in New York State, there was a correlation between female retention in math, science, and technology and the number of these courses taught by women. The correlation did not hold for women's retention in other courses nor for men. (Robst, Russo & Keil, 1996)

High school students in three U.S. states said that a lack of role models was the main reason why girls are less likely to pursue technology careers. (Jepson & Perl, 2002) A similar finding occurred in Scotland. (Durndell, Siann & Glissov, 1990) Twelve women in technology careers credited role models in part for their career choice. (Smith, 2000) Women faculty and graduate students in CS in two American universities believed that the lack of viable role models contributed to the greater female attrition rate. (Etzkowitz, Kemelgor, et al., 1992) In another study, however, girls rejected the notion that the number of female role models bore any relation to the number of girls taking computer courses. (Kwan, Trauth & Dreihaus, 1985) Reinen and Plomp have noted that primarily male computer teachers do not provide role models for girls, but they may be confusing role models with mentors. (Reinen & Plomp, 1993, 1997)

Unlike mentoring, which evidence indicates is effective, I was not able to find any studies that documented a positive relationship between female enrollment and/or retention in technology with a role-model intervention.

Classroom Interactions. Female CS students at Purdue reported in a survey their observation that professors did not treat male and female students equally. (Wasburn & Miller, 2005). Several authors point out that it is the subtle, often intentional, and individually trivial incidents of gender bias that are cumulatively powerful and have the effect of discouraging female participation in technology. (Gatta, 2001; Sanders & McGinnis, 1993; Valian, 1998) The latter speaks of the different expectations we all have about both males and females as "gender schemas" that create the differences in our treatment of them.

Curriculum. Criticism of the standard computer curriculum includes its exclusive focus on programming (Schofield, 1995), its emphasis on basic skills as opposed to problem-solving (Goode, Estrella & Margolis, 2005), and the fact that complex and more interesting projects are often reserved for advanced courses that come too late for most women (Linn, 2005). However, much of the research presumes female homogeneity, manifestly not the case, and does not establish a correlation between curriculum variations and persistence in technology. Most work here falls into the "assertion trap" mentioned earlier.

Two themes run through most of the work on curriculum improvement for girls or women in technology. First and most frequent, make curriculum relevant to real-world concerns, partly by making it cross-disciplinary. Male-oriented and abstract curriculum devoid of social relevance has been of particular concern. (Margolis & Fisher, 2002; Schoenberg, 2001; Schofield, 1995) Margolis and Fisher call for "computing with a purpose" and suggest curriculum "within human and social contexts." (Margolis & Fisher, 2002, p. 52; also Brunner & Bennett, 1997; Burger, 2002) A paper called for curriculum that appeals to females' social and ethical interests (McCormick & McCormick, 1991), while a book of strategies called for "usefulness." (Sanders, 1994) As a remedy, undergraduates created software for local community social service agencies and this course attracted a higher proportion of females than other CS courses. (Jessup & Sumner, 2005) A redesigned university course offered projects that were personally relevant and focused on helping people. (Holzberg, 1997) Infusing technology across the curriculum, especially below the college level, is seen as one way to make curriculum relevant. (Burstyn, 1993; Dain, 1991; Starr, 2000). Several researchers have pointed out girls' and women's preference for contextualized curriculum in which computing and technology in general are seen as tools for solving humanity's problems and enriching humanity's experiences. (Dain, 1991; J. F. Margolis, Fisher & Miller, n.d.-a; Tillberg, 2005) Blum, however, warms that curriculum changes based on commonly accepted gender differences can perpetuate stereotypes, and indeed the risk is obvious. (Blum & Frieze, 2005)

Second, use different curricular approaches and teaching methods to appeal to diverse learning styles. In the UK a "taster" course was created for to attract more girls. (Dain, 1991) Starr emphasizes the importance of having a flexible curriculum to accommodate people's diverse paths to technology. (Starr, 2000; Margolis & Fisher, 2002.)

Teachers and Faculty. Several studies have documented teachers' sexist beliefs about their female students' computer abilities. In Canada, teachers explained gender differences in computing with stereotypes but denied that gender was a consideration in their explanations. (Bryson & de Castell, 1998). A large sample of American high school students of both sexes agreed that teachers, counselors, and parents all believed that computers were more appropriate for males than females. (Shashaani, 1993) Cole and colleagues reported that teachers saw less need for technology in the future of their female students. (Cole, Conlon, et al., 1994) Teachers stereotype computing as a male domain. (Huber & Schofield, 1998). In Japan and Costa Rica, teachers were seen to encourage males more than females. (Huber & Scaglion, 1995; Makrakis, 1993) Middle-school girls did everything their teachers asked of them and did good work, but they were still assessed by teachers has having less of a flair for computing. (Culley, 1988) UK teachers and counselors recognized the existence of gender stereotypes in computing and expressed a commitment to equal opportunity, but saw the source of stereotypes as occurring exclusively outside of school in parents, peers, and the media. (Culley, 1998) The same teacher belief was reported in the U.S. by Opie. (Opie, 1998) These studies matter, of course, because teachers' expectations become self-fulfilling prophecies, work that originated with Rosenthal in 1968 with his *Pygmalion in the Classroom*. (Cooper & Weaver, 2003; Rhem, 1999)

Several researchers have observed that foreign-born computer science instructors at the postsecondary level have cultural biases against females. (Bohonak, 1995; Breene, 1992). In a survey of teachers in 20 countries, Reinen and Plomp found that most computer teachers were male and that most female computer teachers had less confidence in their own skills and knowledge. (Reinen & Plomp, 1993) Cohoon reported that female retention in CS is positively related to their professors' positive attitudes toward women students and negatively related to their professor's belief that female students were not well suited to their major. (Cohoon, 2001, 2002)

What seems to work to improve teachers' gender-related behavior, although not with all teachers, are staff development that emphasizes no personal blame for universally learned gender stereotypes, attention to the WIIFM Rule (What's In It For Me?), praise for progress whenever possible, and the need for teachers to be explicit with students about gender bias because merely modeling exemplary behavior is often not sufficient to counteract the students' sexist notions. (Sanders, 1996, 2005)

5. Special Efforts

Interventions. The literature is full of publications on interventions at all educational levels, far too many to list here. Some describe programs; others merely list recommended interventions. A number of interventions have been discussed above. The National Science Foundation published the most comprehensive source of information on interventions from 250 funded projects; it has an excellent index. (McNees, 2003) When the AAUW Educational Foundation analyzed a decade of funded projects in the U.S. they found that the majority of technology projects were for girls only, were extracurricular, and focused on attitudes rather than academics. (American Association of University Women Educational Foundation Commission on Technology, Gender, and Teacher Education, 2004) Extracurricular projects were typically after-school, weekend, and summer programs with limited and voluntary participation, by definition not involving all girls.

There are several common failings of research, if we can call it that, on interventions. First, virtually none of them present evaluation data; two exceptions are the Computer Mania Day program for middle-school girls, which found improved attitudes (Morrell, Cotten, et al., 2004), and a summer institute program in which high school girls said they were more likely to be involved with technology in the future. (Volk & Holsey, 1997) Second, evaluation of most of these programs would be problematic due to multiple simultaneous interventions. Third, none of them were conducted longitudinally, leaving their ultimate effectiveness unknown.

Teacher Education. Nearly everything on teacher education with respect to gender and technology concerns in-service education with classroom teachers. Wasburn and Miller described workshops for technology faculty and graduate student instructors at Purdue University (Wasburn & Miller, 2005), but all the others deal with K-12 teachers and those concern voluntary participation by teachers. Variations run from short-term teacher training (Chabot Space and Science Center, 2004; Morrell, Cotten, et al., 2004) to training over one to two years (Sanders & Nelson, 2004). Margolis and Fisher described weeklong workshops for high school AP computer teachers at Carnegie Mellon (Margolis & Fisher, 2002), but Sanders presented evaluation data for that project that became available after the book went to press. She found disappointing results in that girls' enrollment increases were likely due to factors other than the gender equity intervention and that girls' enrollment levels were unrelated to the number of intervention strategies carried out by participating teachers. (Sanders, 2002)

Research on gender and technology in pre-service teacher education is nearly non-existent. The AAUW report, *Tech Savvy*, concluded that many teacher education students, most of whom are female, tend to be computer-anxious and have little computer experience. (American Association of University Women Educational Foundation Commission on Technology, Gender, and Teacher Education, 2000) Sanders has pointed out the general lack of attention to the issue and the need for its systemic inclusion in pre-service teacher education. (Sanders, 1997, 2000; Sanders & Campbell, 2001) There is a web-based course on gender and technology for pre- and in-service teachers at the postsecondary and secondary levels (Sanders & Tescione, 2004), but this does not escape the problem of focusing on supplying gender equity materials for teachers while paying no attention to demand, which may be far lower. (Sanders, 1995).

Departmental Change. Reinen and Plomp point out the importance of establishing gender equity policy at the departmental level in elementary, middle and high schools to counteract girls' often lesser access to computers at home. (Reinen & Plomp, 1997) Other papers on this topic concern the postsecondary (tertiary) level. One calls for computer science departments to accommodate the contradiction for women between the tenure clock and the biological clock (Etzkowitz, Kemelgor, et al., 1992). At Carnegie Mellon, changes that occurred included the creation of new entry courses in the School of Computer Science to allow for differential initial knowledge levels, new cross-disciplinary courses, and accepting students with less prior computer experience than previously. (Margolis & Fisher, 2002) In the web course mentioned above, suggested departmental changes include a climate survey among students, a recommendation that the best instructors teach the introductory courses, gender equity education for faculty, and a new-student orientation that includes attention to gender equity issues. (Sanders & Tescione, 2004.)

6. Conclusions

What We Need to Know. This review of the research has raised in my mind some questions about gender and technology to which answers are needed. Consider this a source of dissertation topic ideas.

- We know that parental influence on daughters' technology interests and behavior varies by SES and educational level, but does it vary by racial/ethnic group?
- There is a great deal of research on attitudes and on behavior, but what is the causative direction? Does it vary by student characteristics? If so, which characteristics are relevant?
- Does computer game-playing in childhood lead to technology competence and careers as adults?
- Is stereotype threat a factor in females' computer technology behavior and performance?
- What is the relationship, if any, between role models and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics?
- What is the relationship, if any, between support groups and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics?
- What is the relationship, if any, between collaborative learning and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics?
- What is the relationship, if any, between single-sex learning environments and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics?
- Are there curricular approaches that correlate with persistence in technology? What curricular approaches are better for different groups of learners, and which characteristics are relevant in light of females' (and males') multiple learning styles?
- What approaches to staff development are most effective with different groups of teachers, and which teacher characteristics are relevant?

What We Need to Do. One rather glaring hole in this review is research on teachers from their point of view. What is it that makes teachers want to help close the computer gender gap? Could that motivation or skill set be more widely shared with their colleagues? I bring this up because most developmental work originates in activists' belief in their ability to produce programs and materials that teachers will value and that will be effective in increasing female participation in technology. In other words, we concentrate on supply, not on demand. As this chapter should make clear, while we certainly don't know all the answers we have enough of them to know that the lack of progress is not due to lack of knowledge about what to do. Good ideas, good practices, and good materials exist, and even in easily accessible forms. What does not exist nearly as much is educators' desire to make use of them. It is time for gender equity researchers and advocates to focus on demand.

A great deal of the research on gender and technology represents wasted opportunities. By this I mean that for all the effort that has gone in to providing compensatory programs for girls and women in technology, we would know a great deal more than we do had the programs been conceptualized to permit effective evaluation. Having read nearly 600 articles and papers for this chapter, I am left with the feeling that program developers and researchers don't talk to each other often enough. Closer cooperation between the two groups would help immensely since each truly does need the other for optimal effectiveness. Equally helpful would an understanding from governmental and private funding sources that short-term answers do not serve our long-term needs well. Longitudinal research is expensive but it is necessary, and funders must recognize that reality.

Reflecting the origins of technology, most research has focused on female deficits: their lower experience levels, less positive attitudes, and failure to persist and perform well in educational programs, as compared with males. Research on gender and mathematics, science and engineering, further along than technology, repeatedly points to the value of including 'different" people — women, people of color, people with disabilities, and others —to expand the scope of the questions asked and paths followed. How do the technological disciplines change if they are approached from different points of view, with different desired outcomes, indeed, with different understandings of the disciplines themselves? We need to re-imagine technology, to shift it from what it can do to what it can serve, and in so doing to free ourselves from the conceptual constraints posed by business as usual according to the male model.

Finally, because women are performing at a high level in technology careers, there is no question about women's capability in the field. The issue for education is therefore to remove the barriers that are interfering with girls' and women's access to technology and success in it. This review of the research identifies many ways that barriers have been removed, usually on a small scale, and suggests ways they might be removed on a wider scale in the future.

There are many activists and researchers all over the world who are concerned with gender in technology. Working in non-profit organizations, advocacy groups, universities, government, and research and development organizations, we have limited influence over what happens in the education establishment — in elementary and secondary schools, in departments of computer science at the postsecondary (tertiary) level, in colleges of education that prepare new teachers, in the professional associations that serve them all, and in governmental agencies that set and fund education policy. As long as gender equity in technology depends on the voluntary efforts of activists and researchers trying to influence the education establishment, progress for women will remain slow or nonexistent, or might even regress further than it has already. With more aspects of life invested in technology with each passing year, the senseless waste of so much talent delays solutions for humanity's ills.

As Myra Sadker, the late gender equity advocate, used to say, "If the cure for cancer is in the mind of a girl, we might never find it." Myra died of cancer when she was only 54. What can we do, each and every one of us, to make it possible for that girl to find the cure some day?

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An, annotated and searchable bibliography on gender and technology on about 580 sources, including keywords, can be found at www.umbc.edu/cwit/itgenderbib/
Please note that one keyword is "research review."

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Appendices

- **Appendix E**

  Diversity as Strategy, Harvard Business Review